The Effects of Cardiovascular Exercise on eSport Performance

By

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Abstract

Video games have evolved from a juvenile recreational activity into an avenue for organized competition known as electronic sports (eSports). Cognitive research identifies visual attention, memory, and task-switching as primary determinants of success in eSports. Multiple theoretical frameworks of gaming competence suggest that success in digital gaming relies on problem-solving with a focus on attention and memory. Interestingly, the same cognitive functions also improve as the result of both acute and chronic cardiovascular exercise. This uncovers a clear potential benefit of endurance exercise on eSport performance. Furthermore, results from a series of qualitative studies in eSport athletes (E-athletes) suggest that E-athletes and their employers believe exercise has a positive impact on performance. However, no research to date has observed if there is a relationship between exercise and eSport performance. Therefore, this study aimed to investigate the effects of acute and chronic cardiovascular exercise on eSport performance.

A repeated measures design was implemented in this study to observe the effects of both an acute high intensity interval training (HIIT) protocol and a chronic HIIT intervention on eSport performance. A semi round-robin competition was implemented at four timepoints (C_1-C_4) to measure eSport performance scores as a proportion of wins accumulated to total matches played. Dependent variables of maximal oxygen consumption (VO_2 max), body mass index (BMI), percent fat mass (BF%), and visuomotor performance were measured during pre- and post-testing to assess if changes in eSport performance could be explained by specific physiological or cognitive variables. Logistic regression models were then used to observe the effect each intervention had on eSport performance.

Results of the logistic regression models suggest there is an effect of acute exercise ($p = 0.03$) and a combined effect of acute exercise and a chronic endurance training program ($p = 1.9e^{-5}$) on eSport performance. The effect of chronic endurance training alone was not significant ($p = 0.21$). There was no significant difference in any physiological variable between pre- and post-testing for time or group. There was an effect of time on cognitive flexibility (Trails Task switch cost) ($p = 0.048$) for both groups.

These data from this study serve as preliminary evidence for a positive effect of HIIT on eSport performance. Future research is needed to quantify the exact magnitude of these effects and elucidate the physiological and cognitive mechanisms.

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List of Abbreviations

ANCOVA, Analysis of Covariance

ANOVA, Analysis of Variance

AVG, Action Video Game

a-vO_2 diff, Arteriovenous Difference

BF%, Percent Fat Mass

BMI, Body Mass Index

E-athlete, eSport Athlete

eSports, Electronic Sports

FPS, First Person Shooter

GXT, Graded Exercise Test

HIIT, High Intensity Interval Training

HRR, Heart Rate Reserve

LoL, League of Legends

MOBA, Multiplayer Online Battle Arena

PR, Power Ranking

Q, Cardiac Output

RPE, Rate of Perceived Exertion

SSBU, Super Smash Brothers Ultimate

THC, Tetrahydrocannabinol

TPS, Third Person Shooter

TTE, Time to Exhaustion

VO_2 max, Maximal Oxygen Consumption

VO_2, Oxygen Consumption

Chapter I

Introduction

Video games are a common recreational activity in the United States. Research suggests more than 91 percent of children ages 8-18 participate daily in electronic gaming [1]. Scholars in multiple fields of research have taken an interest in video games due to their rise in popularity. Video game researchers have explored the consequences of violent video games [2-4], the potential health consequences of gaming and video game addiction [5-7], and how the integration of physical activity into video games might combat health pitfalls associated with the sedentary nature of gaming [8-10]. Additional research in gaming has investigated the use of virtual reality to provide safe simulations in multiple careers (e.g., flight simulation, surgery, and sport) [11-13] and the use of video games to improve cognitive function in children with learning disabilities [14, 15]. In sum, a large body of gaming literature examines the use of a popular recreational activity on quality-of-life improvements and job performance. However, gaming recently evolved from a juvenile recreational activity into an avenue for organized competition known as electronic sports (eSports).

The birth of eSports contributed to an increase in video game industry revenue [16] and gave rise to professional eSport organizations (e.g., Cloud 9, Team Liquid, Team Solo Mid, Panda Global). Professional players on contract with organizations may now pursue eSports as a viable career opportunity. Amateur players also have access to more opportunities for competitive play and prize money [17]. Scholars in the fields of law, media, business, sports science, informatics, and cognition have all taken an interest in eSport research due to its rise in popularity and potential for financial gain [18]. Each area fulfills its niche, but cognitive and sport science scholars contribute to most of the eSport performance literature. In eSports performance research, scholars have recently turned the original gaming research question on its head. The question has shifted from “What is the effect of gaming on other aspects of life?”, to “What is the relationship between fitness and cognition on eSport performance?” ([19-23]

eSports performance research is in its infancy. Cognitive performance improves as a result of video game interventions [24-27] or is higher in gamers as indicated by scores on tests of cognitive performance [28-31]. Cognitive research identifies the primary determinants for success in digital gaming as: (1) visual attention, (2) short-term and working memory, (3) information processing, and (4) task-switching [1, 24-29]. Results from these studies align with multiple theoretical frameworks of gaming competence, which suggest that success in digital gaming relies on a problem-solving mind with a focus on attention and memory [32, 33].

Sport science scholars conducted a series of qualitative studies inquiring about physical activity levels of high-level and professional eSport athletes (E-athletes). Results suggested that E-athletes exceeded physical activity recommendations for the general population ([34]-reported 1.08 hour daily average), and more than 50% of E-athletes believed that physical activity improved their performance [34, 35]. Researchers also reported that professional eSport organizations hired personal trainers to design exercise training regimens for their E-athletes [34].

Exercise science research indicates exercise, namely cardiovascular exercise, has a positive effect on indices of cognitive performance [36-42]. Specifically, individuals achieve greater scores on tests of memory [43, 44], attention [45, 46], information processing [47] and task switching [48, 49] after an acute bout of cardiovascular exercise [47, 50-52] or as the result of participation in an endurance training program [37, 40, 41]. Furthermore, highly fit individuals tend to achieve higher scores on tests of these cognitive variables when compared to their low-fit counterparts [53]. In sum, the same cognitive areas which determine success in digital gaming all improve because of cardiovascular exercise.

The eSport performance literature points to a potential benefit of cardiovascular exercise on gaming performance [1, 18, 23, 34, 36]. Theoretical models of gaming competence indicate that attention, memory, information processing, and task-switching contribute to success in digital gaming [32, 33, 54]. These same areas improve because of both acute and chronic cardiovascular exercise. Furthermore, participants and eSport organizations seem to believe there is a positive effect of physical activity on eSports performance, as evidenced by physical activity levels and training schedules of high level and professional E-athletes. However, there is no study to date that has observed the effect of an exercise intervention on E-athlete performance in competition. Therefore, the purpose of the proposed study was to conduct the first experimental trial interrogating the acute and chronic effects of cardiovascular exercise on competitive eSport performance scores.

Specific aims:

Determine the effects of cardiovascular exercise on competitive performance scores in E-athletes:

Aim 1: The effect of cardiovascular fitness on competitive eSport performance scores.

Aim 2: The acute effect of a bout of cardiovascular exercise on competitive eSport performance scores.

Aim 3: The chronic effect of an 8-week prescribed endurance training program on competitive eSport performance scores when an exercise group is compared to a non-exercising control group.

Hypotheses:

Hypothesis 1: Highly fit participants will achieve greater initial competitive eSport performance scores when compared to their low-fit counterparts.

Hypothesis 2: Participants who complete a single bout of high-intensity cardiovascular exercise will achieve greater eSport performance scores when compared to a non-exercising control group.

Hypothesis 3: Participants who complete a prescribed 8-week endurance training program will experience greater improvements in competitive eSport performance scores when compared to a non-exercising control group.

Chapter II

Review of Literature

Introduction

Video gaming has evolved from a popular recreational activity into a professional career opportunity in the form of electronic sports (eSports) [55-57]. eSports refers to the play of a variety of digital games in a competitive setting [54]. Participant inputs take place through a human electronic-system interface such as a console or personal computer [58]. Participants in eSports are referred to in compeition and in the literature as E-athletes.

eSport's popularity has increased drastically since its inception in 2000. Live and livestreamed eSports reached an audience of 235 million viewers in 2015, and this number contines to steadily increase. Professional eSports viewership trends predict an audience of over 1.1 billion by December 2022 [59]. Survey data suggests that young adult men prefer watching eSports to traditional sports [60]. The League of Legends (LoL) championship acquired the same number of viewers as the year's National Hockey League Stanley Cup (8.5 million simultaneous viewers) in 2013 [61]. That same LoL championship sold out the Staples Center in Los Angeles, CA, reaching same live viewership as the 2012 National Basketball Association Finals [62]. Additionally, it has been reported that overall viewership for some eSports has surpassed the viewership of the Major League World Series and National Basketball Association Finals [63, 64]. Increases in viewership yields an additional increase in financial gain. Industry revenues for eSports excdeed $696 million in 2017 [65]. The revenue of the gaming industry surpassed the combined revenue of the film and music industries in 2020 [16]. Additionally, E-athlete earnings have exceeded $1.5 billion [59, 64]. The widespread rise in popularity of eSports has created a new opportunity for multiple fields of research including cognitive, sport, and exercise science.

Current Areas of Research in eSports

The state of eSports research is in its infancy. eSports research can historically (from 2000-2020) be categorized in seven parts: 1) business, 2) media, 3) sociology, 4) law, 5) informatics, 6) sport science and 7) cognitive science [18].

Business, Media, Sociology, and Law

Business literature in eSports describes the eSport ecosystem. This qualitative research assesses game popularity as well as the motivation of players and consumers [18, 66, 67]. Literature in eSports media assesses advancements in technology [68], livestreaming [69] , spectatorship [70], media and communication [71], community formation [72, 73], and live celebration [74] to explain various aspects of the eSport viewer and player base. Sociology literature also observes the relationship between eSport participants and live audiences [75, 76]. There is additionally a unique focus on the involvement of women in professional play [77, 78], gender identity [79], gender roles in eSports [78], gender inequality [80, 81], and the perception of gender by eSport participants [81]. Law literature in eSports details the effect of eSport culture and industry on internet law, and the influence of intellectual property and gambling law on the structure of eSports.

Sports Science and Informatics

Most sport science literature in eSports attempts to define eSports as a sport by comparing it to definitional frameworks of traditional sports [82-85]. There is currently debate over the classification of competitive gaming as a sport. Sports science scholars combine

Gutmann's (2004) definition of sports from the field of sport sociology [82], and Suits' (2007) definnition from the field of sports psychology [86] to assert that for an activity to be considered a sport it must fit seven characteristics: 1) play; 2) organization and governance of rules; 3) competiton; 4) be comprised of skill instead of chance; 5) include physical skills; 6) have a broad following; and 7) have achieved institutional stability where institutions have rules which regulate it and stabilize it as a social practice. Some scholars believe that eSports fulfill 5 of the 7 characteristics: 1) eSports involve voluntary play; 2) eSports are governed by sets of rules; 3) eSports include competition featuring a winner and a loser; 4) eSports have outcomes determine by skill instead of chance; and 5) esports have a broad following beyond a local fad [68, 85, 87-89].

Debate arises concerning the inclusion of physical skills and institutional stability in eSports. eSports need centralized rules for stabilization for them to be considered more than a juvenile recreation activity [87]. The different types of eSports (e.g., multiplayer online battle arenas, fighting games, first-person shooters, third-person shooters, and sedentary sport simulation) make it difficult to have a centralized ruleset [55]. Furhtermore, in many cases the only physical skill required in eSports is superior manual dexterity to the opponent [90].

Scholars may never reach a definitive conclusion in the "eSports as a sport" debate. However, universities and proffessional organizations have already begun integrating eSports into the traditional sport framework. Collegiate eSports in the United States begain in 2014 when Robert Morris University in Pittsburgh and the University of Pikeville in Kentucky offered varsity sport scholarships for eSports [61]. There are 175 colleges and universities who offer scholarships scholarships for E-athletes, and more than 500 teams at the club level in the United States and Canada as of Janurary 2021. [87]. eSports have been considered a sport in China since

2003, and E-athletes under contract with sport organizations have been considered proffessional athletes in the USA since 2013 [87]. Furthermore, eSports were an event in the Asian indoor martial arts games in 2017, and the Olympic Council of Asia decided that eSports will be featured competitively in the 19th Asian games in 2022 [54, 83]. There is a growing field of research in eSports performance due to the potential financial and career opportunities.

Informatics literature primarily involves data mining of variables to assess eSport performance and player interaction via team and group dynamics [18, 91-93]. A recent data mining study used professional StarCraft 2 player inputs to develop an algorithm to predict the use of unexpected in-game strategy. The algorithm was used to assess learning behaviors in professional E-athletes [94]. A small subsection of informatics literature uses physiological data to assess eSport performance [92]. However, the primary field of eSport research dedicated to assessing performance is the cognitive field.

Cognitive Literature in eSports

Cognitive literature in sports science observes the interaction between gaming and four cognitive variables: 1) attention, 2) memory, 3) information processing, and 4) task-switching.

Attention

Attention is the ability to focus the mind on a task or object [95]. Attention is broken down into sustained attention, vigilance, selective attention, and visual attention [96]. There is a primary focus on visual attention in cognitive studies of eSports. Visual attention can be measured a number of ways, including useful field of view tests, visual search tasks, compound search tasks, attentional capture tasks, oculomotor capture tasks, target localization tasks, lane keeping tasks, spatial cueing tasks, attention cancellation tasks, attentional blink tests, visuomotor mapping, enumeration tasks, and serial reaction time tasks [1].

Memory

There is a focus on working and short-term memory in eSport research. Working-memory provides temporary storage and manipulation of the information necessary for complex cognitive tasks like language, comprehension, learning, and reasoning [97]. Short-term memory is the temporary portion of working memory [98]. Memory as a variable of cognitive performance in eSports is measured using: partial report performance tasks, colored stimuli tests, complex shapes tasks, continuous performance tasks, n-back tests, filter tasks, enumeration tests, and wordlist recall tasks [1].

Information Processing

Good information processing is defined by several characteristics: 1) the ability to plan thought and behavior; 2) the ability to monitor and change a behavior after failure; 3) excellent short-term memory; 4) automatic implementation of strategy; 5) possession of knowledge over important concepts; 6) appropriate confidence; and 7) belief that self-improvement is attainable and desirable [99]. Information processing is measured as a cognitive performance variable using the following tests: partial report performance task, anti-cueing task, change detection task, target identification task, line bisection task, random dot kinematogram task, prime discrimination task, mental rotation task, and letter detection tasks [1].

Task-Switching

Task-switching refers to the frequent shift between cognitive tasks. Task-switching literature often observes the mental and neural processes required to switch between a number of tasks of varying difficulty [100]. The “switch cost” or time to switch between tasks, is often measured as a cognitive performance variable. Task-Switching performance is measured using the following tasks: Congruent task-switching tasks, incongruent task-switching tasks, simultaneity judgment task, trails tasks, temporal-order tasks, task switching-paradigms, dual task switching paradigms, dual-task tests, multiple identity tracking tasks, and number switch tasks [1].

Cognitive literature in eSports assesses visual attention, working memory, information processing, and task switching as well as the cognitive differences between non-gamers and gamers [18]. The literature also explores how video game interventions affects participants’ scoring on cognitive testing, describes determinants of success in E-athletes, and provides theoretical models of success in digital gaming.

Action Video Game Interventions

eSport and cognition studies often observe the effect of Action Video Games (AVGs) on performance in cognitive testing. AVGs fulfill the following criteria: 1) fast paced; 2) high degrees of perceptual and motor load; 3) high degrees of working memory, planning and goal setting; 4) emphases on switching between focused and distributed states of attention; and 5) a high degree of clutter and distraction [19]. AVGs place a large amount of cognitive stress on areas such as attentional control, working memory, and executive function [1, 25, 31]. Participants improve performance scores on tests of visual attention, [24-26, 101-104] memory [105], information processing [101, 106-108], and task-switching [27, 107, 109-111] as a result of AVG interventions in non-gamers.

Gamers versus Non-Gamers

A large body of cognitive eSport literature focuses on the cognitive performance comparison between AVG gamers and non-gamers. There are numerous studies to date with findings that suggest AVG gamers perform better than non-gamers on cognitive tasks of visual attention [27-30, 102, 103, 107, 112-125]. In addition, AVG gamers perform better than non-gamers in cognitive tasks of information processing [29-31, 124, 126-134], memory [30, 125, 135-137], and task-switching [30, 31, 109, 110, 125, 137-141].

There has been discussion regarding eSports as a new window on neurocognitive expertise [142] due to the results of the numerous studies demonstrating the differences between AVG gamers and non-gamers. Additionally, scholars developed multiple theoretical frameworks of success in digital gaming.

Models of Game Competence

Models of game competence describe the skills required for success in gaming [54]. One model of game competence describes digital gaming as an intricate problem-solving process. In this model, success is influenced by a problem-solving mind, inducive reasoning, visuo-spatial competence, hand-eye coordination, and social competency [54]. Additional models of game competence include the influence of sensory-motor control, emotion, social competence, and cognitive ability. The identified cognitive abilities include attention, strategic thinking, problem solving, planning, memory, and knowledge [32, 33]. Two of these cognitive principles (attention and memory) are observed to be more advanced in AVG gamers both qualitatively and as the result of intervention. These cognitive variables, in addition to information processing and task-switching, also improve as the result of exercise intervention in exercise science research [1].

Exercise Science eSport Literature

Acute Physiological Effects of Gaming

Current exercise science studies in eSport primarily observe the effect of a single gaming bout on acute physiological responses. Single-session gaming research dates back to 1991 when researchers observed increases in heart rate, blood pressure, and oxygen consumption (VO_2) in 32 men and women after a 30 minute session of Ms. Pac Man [143]. These findings were supported in 2006 when researchers found increases in systolic blood pressure, diastolic blood pressure, heart rate and VO_2 in twenty-one, 7-10 year old boys following a session of a fighting game [144].

Recent studies also show increase in cardiovascular variables after a single session of gaming. Researchers investigated the heart rate response in 24 young adult males during a session of the third person shooter (TPS) Fortnite. Both mean and peak heart rate were greater during gameplay compared to resting heart rate, implying that AVG gamers experience a stressful physiological response to a session of competitive gameplay [145]. A limitation of the study is that competitors played from home, which does not simulate the in-person events in traditional competitive play. eSports can be played either online from home (in a familiar environment) or in person in front of a crowd. The authors deduced that the peak and mean heart rate response may be even greater than they measured if the games were played live in person. This is supported by a study in which hormone levels were measured in response to a session of the multiplayer online battle arena (MOBA) LoL. The experimental group played against other players, and the control group played against non-player computers. There were no differences between groups in circulating levels of testosterone, aldosterone, dehydroepiandrosterone, androstenedione, or cortisol. The authors attribute these null results to the fact that the gaming occurred in a familiar environment, and indicate that competitions taking place in a familiar informal familiar environment may not elicit a large physiological response [146]. An additional study observed the effect of a number of physiological variables including respiration rate, heart rate, and blood pressure following a session of gaming in a MOBA and first person shooter (FPS) game [147]. Respiration rates during gameplay significantly increased in both the MOBA and FPS groups. There were no differences in heart rate or blood pressure for either the MOBA or FPS group. However, heart rate increased while gaming in each group, and participants reached peak heart rate significantly faster in the first-person shooter group. It should be noted that FPS games are typically considered AVGs, while MOBAS are not.

Researchers observed the effects of violent video game playing on blood pressure and appetite perception in normal-weight young adult males in a randomized controlled trial on violent video games. Researchers randomized 48 non-smoking, normal weight young adult males into either a violent video game, non-violent video game, or television watching group. The researchers monitored blood pressure and heart rate and provided visual analog sales to the participants to measure appetite perception and stress. visual analog scales are a 100 mm line on which the participant typically rates their perception of a variable from 0 to 100. Heart rate and blood pressure increased in both groups. However, both diastolic blood pressure and appetite suppression increased the most in the violent video game group [148], implying potential differences in physiologic responses to violent video game playing than other sedentary behaviors. It should be noted that the violent video game in the study (Grand Theft Auto V), is an AVG.

Exercise and Cognition

The empirical evidence of a direct benefit of exercise on eSport performance is lacking. However, there are plenty of studies that demonstrate cognitive benefits of exercise, particularly cardiovascular exercise. There are three primary categories of exercise science and cognition: 1) the acute effect of a bout of exercise on cognitive performance; 2) the chronic effect of an endurance training program on cognitive performance; and 3) the association between fitness level and cognitive performance. To properly conduct an aerobic exercise study, researchers must measure each participant's aerobic power. The gold standard for a measurement of aerobic power is maximal oxygen consumption (VO_2 max) during either treadmill or cycle ergometry testing [149].

Oxygen Consumption and VO_2 Max Testing

VO_2 max is the maximal measure of the cardiovascular system to deliver oxygenated blood to muscle involved during dynamic exercise [150]. It is the clinical surrogate of cardiorespiratory fitness [151]. The Fick equation describes VO_2 [152].

$$\text{Fick equation: } VO_2 = Q * (a\text{-}vO_2 \text{ diff})$$

In the Fick equation, VO_2 is a function of cardiac output (Q), and arteriovenous difference ($a\text{-}vO_2$ diff). Q is the product of the heart rate (number of heart beats per minute) and the stroke volume (amount of blood pumped per heartbeat). [153]. The $a\text{-}vO_2$ diff is a representation of the amount of oxygen in a given volume of blood that is exchanged via tissues during one pass of systemic circulation [153]. Thus, the Fick equation explains that oxygen consumption increases whenever there is an increase in heart rate, stroke volume, or arteriovenous difference.

Metabolic demand increases with exercise intensity. Cardiac output increases linearly with an increase in metabolic rate required during a specific exercise bout. This is explained by both an increase in heart rate up to 100% of VO_2 max and an increase in stroke volume up to roughly 40-60% of VO_2 max [154]. Arteriovenous difference also increases when there is an increase in metabolic demand. The oxidative production of adenosine triphosphate by skeletal muscle also increases with metabolic demand. The result is an increase in the amount of oxygen taken up by skeletal muscle during exercise for aerobic metabolism. In sum, VO_2 increases during exercise [153].

VO_2 max changes occur with any alterations in maximal heart rate, maximal stroke volume, or maximal arteriovenous difference. Chronic endurance training yields improvements in VO_2 max. The increase in VO_2 max can be attributed roughly 50% to an increase in maximal Q, and 50% to an increase in a-vO_2 diff [155]. As there are no increases in maximal heart rate because of endurance training, the increase in Q can be explained by an increase in maximal stroke volume. In turn, increases in maximal stroke volume are explained by increases in end diastolic volume [156], contractility [157], and total peripheral resistance [153]. Improvements in maximal a-vO_2 diff as a result of endurance training are due to three separate adaptations: 1) increase blood flow to working muscle during exercise; [150] 2) increased capillary density [158] in the working muscle; and 3) increased mitochondrial density in the working muscle [159]. In sum, maximal VO_2 increases because of an endurance training program.

When VO_2 max of a participant is obtained, a percentage of VO_2 max can be used to prescribe an acute bout or chronic endurance training program. (i.e., Participants perform a series of sprint intervals at 170% VO_2 max for 30 seconds).

Acute Effects of Aerobic Exercise on Cognitive Performance

A bout of aerobic exercise may improve performance on a wide range of cognitive performance tests [51, 160, 161]. The areas of cognition that benefit from cardiovascular exercise are the same areas that AVG players score well on during cognitive testing and include attention, memory, information processing, and task switching. The most well documented effect of exercise on cognitive performance is the acute effect of a bout of cardiovascular exercise on multiple indices of attention. There are many studies with findings indicating that individuals perform better on cognitive tests of attention after a bout of cycling [45, 48, 162-172], treadmill walking [173], treadmill running [162, 174], and high intensity interval training (HIIT) [169, 175, 176]. Participants achieve higher scores on cognitive tests of memory [44, 167, 177-179], information processing [47, 52], and task switching [48, 50, 166] after a single or multiple bouts of cardiovascular exercise.

The acute effect of exercise on cognitive function is well documented. However, every acute bout of exercise is a stimulus for chronic adaptation, causing structural and physiological changes that change the way the body responds to a stimulus [180]. As such, there is a body of literature on the chronic effects of endurance training on cognitive performance. The primary areas of study in the chronic effect of endurance are attention, memory, and task-switching.

Chronic Effects of Aerobic Exercise on Cognitive Performance

Chronic endurance exercise and cognitive performance literature describe two phenomena including the association between aerobic fitness and cognitive performance, and the effect of implementing an endurance training intervention on cognitive performance. Several studies have noted meaningful associations between high aerobic fitness levels and positive performance scores on cognitive tests of attention across all age groups [40, 53, 95, 181-186]. Researchers used a graded exercise VO_2 max test (GXT) to separate 57 young adult males into fitness categories. Highly fit male participants scored better on tests of both selective and sustained attention than their low-fit counterparts [40]. Researchers observed that participants with a high VO_2 max achieved higher performance scores on tests of selective attention, sustained attention, reaction time, and task-switching [53] in 22 young women. Researchers in an additional study used a GXT to separate young adult males into low and high fitness groups. The high fitness group achieved higher performance scores on tasks of sustained attention [185]. Researchers used the Rockport 1-Mile Walk Test to separate participants into fitness groups in 64 healthy young adult female participants. Higher fit participants demonstrated greater selective attention [95].

There is also a relationship between fitness level and performance in tests of task switching and memory. Authors of two separate studies both report better performance on task switching tests in highly fit compared to low-fit participants in both young and older adults [187, 188]. Researchers report better performance in switch cost tasks in physically active adults compared to sedentary adults in the young adult population [189]. Researchers report a positive correlation between VO_2 max and accuracy on tests of working memory in older adults [190]. Additionally, researchers have observed an association between high levels of physical activity and high performance scores on tasks of working memory [191].

Children [192] and older adults [41, 193] tend to obtain higher scores on cognitive tests of reaction time and attention as a result of an endurance training program. Additionally, researchers have compared the effects of endurance training, resistance training, and balance training on attention. Results indicate that cardiovascular exercise has the greatest effect on both performance of cognitive tests of attention and neuroelectric measurements of attention [41]. Interestingly, the only study investigating the effect of endurance training on attention in younger adults did not observe any positive results [194]. However, the researchers used a low intensity training program (50% of peak power), only trained in one leg, and implemented a four-week training period. The effectiveness of this low intensity, short duration, unique intervention to elicit change at any level in any system should be called into question.

Participants also tend to achieve higher scores on cognitive tests of memory following a chronic endurance training program [195]. Researchers observed large positive changes in visuospatial memory from baselines and compared to a stretching group after three months of a prescribed cycling intervention in 56 participants [196]. Researchers implemented a six-month cycling intervention in middle aged adults. Participants in the exercise group achieved higher scores on tests of episodic memory compared to the control [197]. Researchers observed changes in memory following two different intensity cardio intervention protocols in middle aged adults in a combined treadmill-cycling study. The high intensity exercise group had greater positive changes in working and visual memory than in the low intensity exercise group after 12 weeks of training [42]. Additionally, researchers report improved accuracy on working memory tests after nine months of long-duration aerobic exercise [43]. Results from one study indicate that participants in a chronic treadmill walking intervention also tend to achieve higher performance scores on cognitive tests of task-switching [49].

Physical Activity Levels of E-Athletes

There is concern regarding the health of eSport athletes due to the sedentary nature of eSports. A series of studies entitled "Do E-Athletes Move?" assessed the physical activity levels of E-athletes. E-athletes of varying skill completed surveys regarding their physical exercise routines and training schedules. Thirty-one of the respondents were professional E-athletes (i.e., under contract with an eSport organization) and 84 were unsigned high-level players determined by their national rankings. The results of the study imply that E-athletes are relatively active. High level and professional E-athletes self-report 1.08 hours exercising per day. Interestingly, 47% of the respondents maintain an active lifestyle as a means to upkeep their overall health, and 56% believe that physical activity has a positive effect on their performance in competition [34, 35]. The authors conclude that while the primary motivation for physical activity is health, a portion of the player-base believes that physical activity may improve their performance. However, the authors note that there currently does not exist any literature about the type or duration of exercise that is optimal for E-athletes [34].

Conclusions and Purpose Statement

eSports is a rapidly growing field of interest for competitors, viewers, and the video game industry. As such, it has recently attracted scholars in multiple fields of research, including cognitive and exercise science. The cognitive literature suggests that AVG interventions improve cognitive performance scores in tests of attention, memory, information processing, and task-switching. Results from cross sectional studies also indicate that AVG players perform better on these same cognitive tests than non-gamers. These four cognitive variables have been identified in multiple models of game competence to elucidate the mechanisms of success in digital gaming. Interestingly, review of the exercise science literature suggests that performance on tests of these same four cognitive variables improve both after an acute bout of exercise, and as the result of an endurance training program. All this evidence points to a beneficial effect of cardiovascular exercise on digital gaming performance. It seems that players and eSport organizations believe that exercise may improve performance. Professional and high-level E-athletes report high activity levels, and a subsection of these E-athletes believe that physical activity has a positive effect on their performance. However, despite the cultural belief that physical activity improves gaming performance, as well as the evidence in the cognitive and exercise literature pointing toward a potential benefit of endurance training on digital gaming performance, there has not been a single study to date that employed either an acute or chronic exercise intervention and observed its effect on performance in E-athletes. Therefore, the purpose of this proposed study was to conduct the first randomized controlled trial investigating the acute effect of cardiovascular exercise and the chronic effect of an endurance training program on metrics of competitive performance in eSport athletes.

Chapter III

Methodology

Study Design

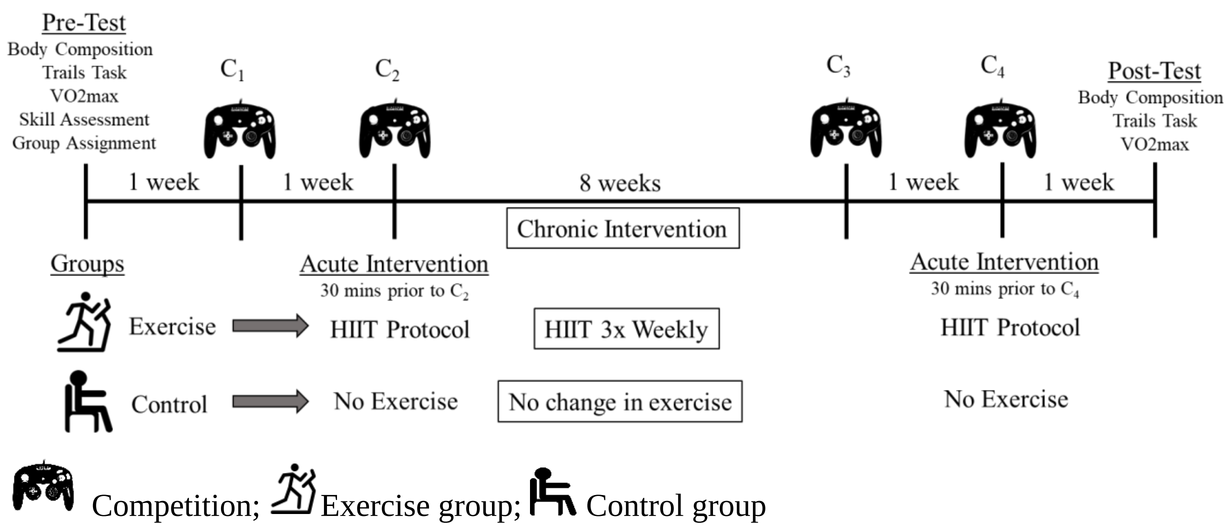


Figure 1. Study Design

A 2 x 4 [group (control, exercise) and time (C_1-C_4)] repeated measures design was implemented in this study. The dependent variables of body composition, maximal aerobic power (VO_2 max) , visuomotor performance, and eSport performance were assessed through bioelectric impedance analysis [198], Trails A and B Tasks [199], open circuit spirometry and a treadmill Bruce Protocol [200] and Super Smash Brothers Ultimate (SSBU) results; respectively. eSport performance was assessed at four specified timepoints, while all additional variables were assessed during pre- and post-testing.

Participants

Researchers recruited 28 active competitors in the Alabama SSBU community ages 17 – 25 (26 male (22.2 ± 2.27), 2 female (21 ± 1)). Researchers obtained written informed consent from each participant prior to any testing. Participants were free from any disease, illness, visual impairments, acute injury, joint disorder, pathology, or any other condition that would preclude them from safely and effectively participating in exercise or gaming. During the consenting process, a member of the research staff described all risks associated with exercise to the participants. The researchers also described the potential beneficial effects of participation in an exercise program. All protocols were approved by the Auburn University Institutional Review Board (Protocol#21-350).

Study Procedures

Assessment Protocols

During the initial visit, researchers performed an assessment that included body composition, manual Trails Task, digital Trails Task, VO_2 max test, and initial game skill assessment.

Body Composition

Researchers determined body composition of each participant using the SFB7 bioelectrical impedance spectroscopy analyzer (Impedimed; Pinkenba, Queensland Australia). Researchers instructed participants to arrive for body composition testing following a 12 hour fast from alcohol and fully hydrated. The research team also instructed participants to refrain from exercise and caffeine consumption two hours prior to arrival for body composition testing. Researchers conducted a urine specific gravity test via portable refractometer (V-Resourcing, Hunan, China) to ensure participant hydration status. Participants were considered hydrated if urine specific gravity value was below 1.025. If participants were not hydrated, they were asked to consume 16 fluid oz. of water and re-assessed 15 minutes later. This was repeated as needed. When the participant was properly hydrated a member of the research team instructed the participant to take off all footwear and lay supine on a treatment table. A researcher then cleaned the four areas of the skin where electrodes would be placed with an alcohol swab: 1) the midline of the ulnar styloid process; 2) 5 cm distal (toward the phalanges) to the first area; 3) between the medial and lateral malleolus; and 4) toward the phalanges 5 cm distal to the third area. After cleaning the areas, researchers used a gauze pad to lightly debride the cleaned areas and place an electrode (Impedimed; Pinkenba, Queensland, Australia) at each location. An alligator clip was then connected to the probe end of each of the four leads, ensuring that the metallic part of the clip was in contact with the conductor side of the electrode tab. Researchers entered all anthropometric data into the system interface and then conducted body composition measurements. Three measurements were taken 15 seconds apart. Researchers recorded the average fat mass percent (BF%) and body mass index (BMI).

Manual Trails Task

The Trails A and B Task was used as a measurement of visuo-motor performance. Researchers described the Trails Task to participants as a “brain game.” In the first task (Trails A), the researcher instructed the participants to draw a line to each number, starting with number 1, and progressing in ascending order (i.e., 1-2-3-4-5 and so on). The researcher explained the four rules: 1) the participants drew a line from number to number in increasing order; 2) the participant was not allowed pick up their pen; 3) the participant could not speak aloud; 4) if the participant made a mistake, the researcher said “No” and pointed to the last location on the page where the participant was correct. The participant then picked up their pen, went back to that area, and resumed the task. Participants first completed an 8-number example (refer to Figure 2). Participants then completed the 25-number Trails A Task. Researchers recorded the total time for completion of Trails A, timing from when the researcher said “begin” and ending when the participant connected the line to number 25. The Trails Task assessments were completed in a quiet, empty room with no visual or audio distractions. The researcher overseeing the Trails Task session did not wear any distracting clothing or jewelry and oversaw all Trails Task sessions for this study. The same script and same Trails path were used for all Trails A Task session (refer to Figure 2).

Participants repeated the same process with Trails B. The Trails B test contained both numbers and letters. Researchers instructed participants to draw a line from number to letter to number to letter, both lists in ascending order (i.e., 1-A-2-B-3-C and so on). Participants completed an 8-item example of Trails B followed by the 25-item Trails B Task (refer to Figure 2). Researchers recorded total time for Trails B in the same fashion as Trails A. Researchers recorded Trails Task switch cost as the difference in time for Trails A and B (B – A).

Digital Trails Task

Participants completed a digital version of the Trails A and B Tasks after completion of manual Trails A and B. Members the Auburn School of Engineering developed a digital Trails A and B Task utilizing the same paths as the manual version. In the digital version of the test the paths appeared on a computer screen. Participants utilized either a Switch (Nintendo, Kyoto, Japan) or GameCube (Nintendo, Kyoto, Japan) with USB plug-in to complete the task. Participants utilized the left joystick on the controller instead of drawing a line from item-to-item with their hands. The digital version of the Trails Task was administered by the same researcher as the manual version following the same script. This study also served as a validation study for the use of the digital Trails task. Both pre and post digital Trails Task times were compared to the manual Trails Task times for each participant.

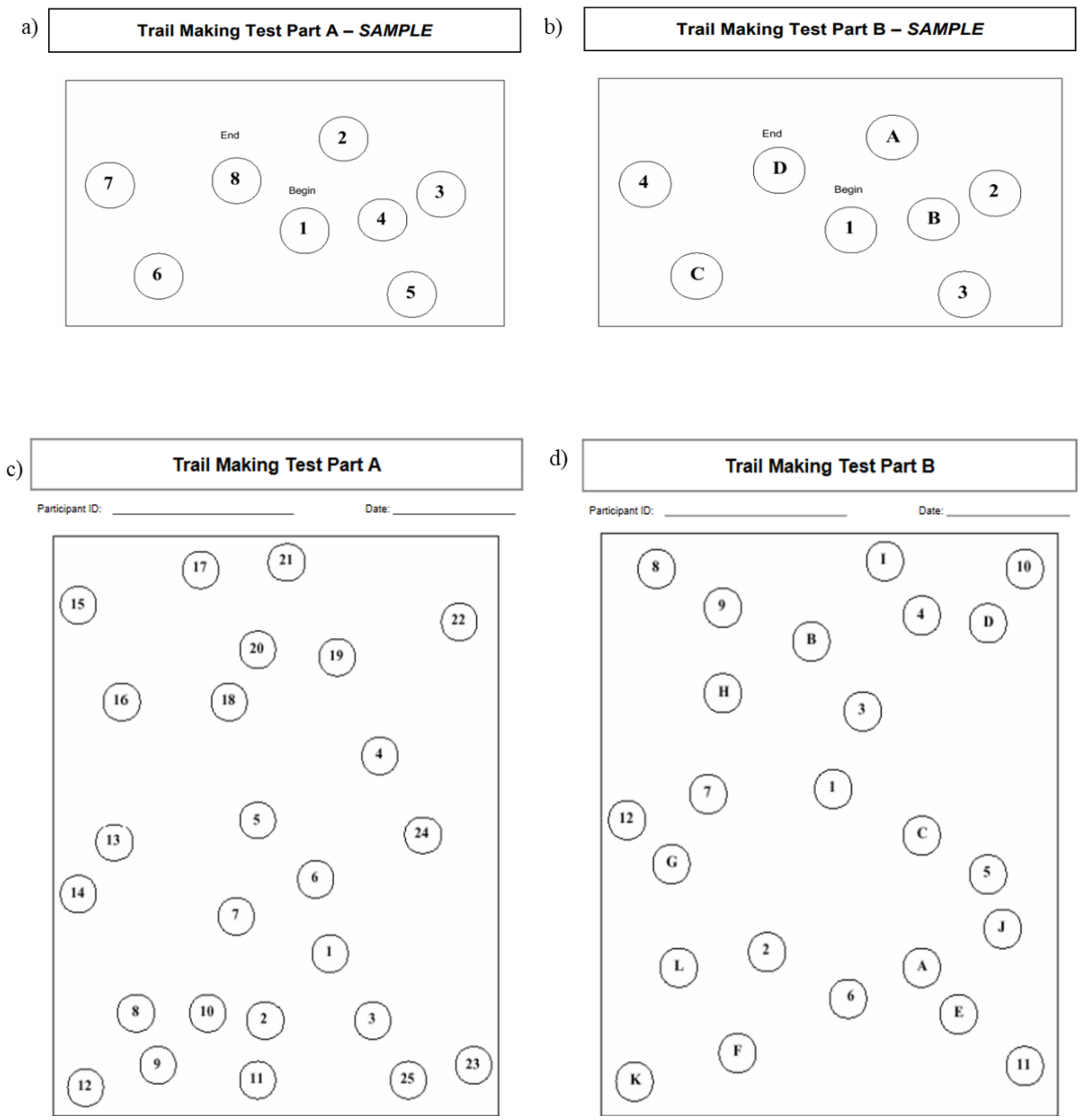


Figure 2. Trails Task paths used for all manual and digital tests a) eight-item sample for A side b) eight-item sample for B side c) 25-item timed A side d) 25-item timed B side.

VO_2 Max Testing

A VO_2 max test was used to determine maximal aerobic power utilizing the graded treadmill Bruce Protocol [200] (Table 1). The treadmill protocol produces a greater maximal oxygen consumption than cycle ergometer protocols [201]. Pulmonary gas exchange was measured using open circuit spirometry and a metabolic cart (Parvomedics, Salt Lake City, Utah). Participants were outfitted with an eq02+ Life Monitor (equiVital, Cambridge, UK) for live monitoring.

Participants walked at 1.0 mph for 3 minutes to warm-up before the test began. Following warm-up, participants began the GXT at Stage 1 (1.7 mph, 10% grade). Exercise speed and grade increased every 3 minutes according to the Bruce Protocol until voluntary termination Tests were considered valid if one of the following criteria were met in addition to voluntary termination: (1) respiratory exchange ratio ≥ 1.15; (2) a plateau in oxygen consumption determined by a change lower than 100 ml/min in the last 30 s of the previous stage; or (3) a heart rate within 10 beats/minute of the age-predicted maximal heart rate (220-age). Researchers determined the participants' VO_2 max using the peak oxygen consumption during the protocol measured via open-circuit spirometry. Researchers used an OMNI Scale (0-10) during VO_2 max testing as a measurement of perceived effort. A member of the research staff described 0 as no effort and 9 as maximal effort. If the participant indicated that their effort level reached a 10, the test was immediately terminated. The full OMNI scale is provided in Table 2.

Table 1. The Bruce protocol graded exercise treadmill test for VO_2 max.
Note: *min*, minutes; *mph,* miles per hour

Stage	Duration (min)	Speed (mph)	Grade (%)
1	3	1.7	10
2	3	2.5	12
3	3	3.4	14
4	3	4.2	16
5	3	5	18
6	3	5.5	20
7	3	6	22

Table 2. Modified OMNI Scale

Perception of Effort	Description
0	No effort; "You are lying down doing nothing"
1	
2	Easy
3	
4	Somewhat easy
5	
6	Somewhat difficult
7	
8	Difficult
9	Extremely difficult; "Maximal Effort"
10	Stop test immediately

Initial Skill Assessment

All participants compete regularly in SSBU tournaments outside of the study. Results from these tournaments are recorded in a public database in the data section of the PGStats website (Panda Global, Detroit, MI, USA). Participant skill was determined by their results in tournaments (expressed as a percentile) during the eight weeks prior to data collection (November 2021 and January 2022).

Assignment of Groups

Researchers matched participants into pairs based on game skill (as described above) and baseline VO_2 max determined from baseline pre-testing. One participant from each matched pair was randomly assigned to either the Exercise or Control group so that n = 13 for each group by a research team member who did not know the participants

Interventions

Competitions

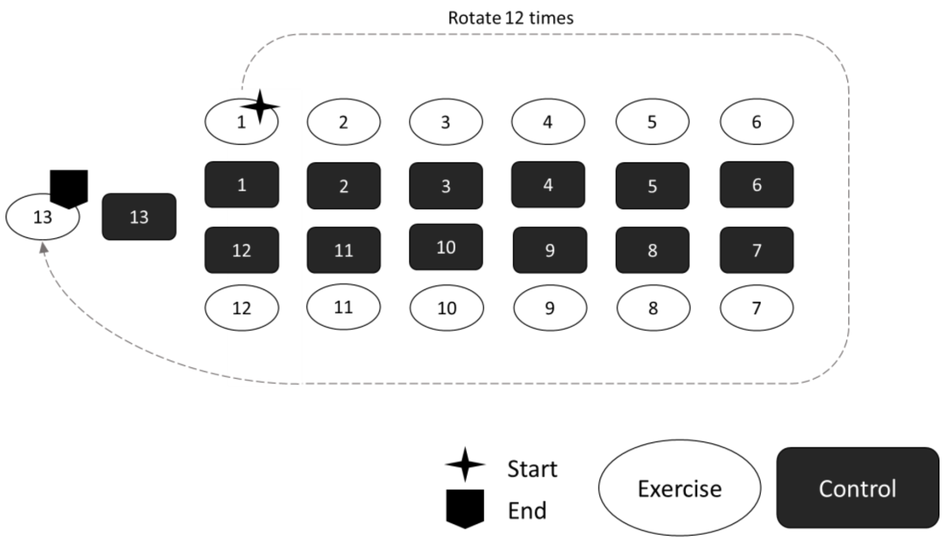


Figure 3. Competition format. Numbers represent individual participants at gaming stations. Exercise participants (numbers in ovals) rotated left, the participants in the control group remained stationary.

All competitions were semi-round-robin style SSBU competitions. SSBU is a platform fighting game with two competitors playing one versus one on an agreed upon map (stage) with three lives (stocks). Every competition in this study utilized the unified Alabama SSBU ruleset: 1) three stocks, 2) seven-minute time-limit, and 3) standard stage-list pick/ban system. The goal of each game was to eliminate all three of the opponent's stocks. The participant who eliminated all three of their opponent's stocks won the game. The winner of the first game banned two stages from a provided stage-list, and the loser of game one picked the next stage. The first participant to win two games won the set. In a round-robin style format, every participant competes against every other participant (i.e., if there are 16 entrants, each participant plays 15 sets). The competition style implemented in this study was semi-round-robin, in which the participants only competed against participants in the opposite group. There were four competitions total, labeled C_{1-4} respectively. Competitions C_1 and C_2 served as data collection for the acute arm of the study. Competitions C_3 and C_4 served as data collection for the chronic arm of the study (refer to Figure 1).

Acute Intervention

Participant in each group gathered in the competition area for 30 minutes to ensure they were sedentary and that both groups had equal practice time prior to C_1. In all competitions, every member of the exercise group competed against every member of the control group in a best of three set. Researchers recorded set wins for each participant. One week following C_1 participants returned to the competition area for C_2. Control group participants gathered for 30 minutes of sedentary time. Participants in the exercise group met with a member of the research team to complete an acute bout of high intensity interval training (HIIT) (Figure 4). Researchers fit each participant with an eq02+ Life Monitor (equiVital, Cambridge, UK) monitor to track exercise intensity via heart rate reserve. The researcher administered the acute bout of exercise to all participants simultaneously. The participants completed 4 bouts of 30 second all-out sprint intervals, with self-selected intensity and 4-minute active rest intervals between each bout. Researchers described "all-out intensity" as the second-last stage of the Bruce Protocol during VO_2 max testing. This protocol was adapted from a cycle-ergometer protocol used in a sprint interval training study [175]. An all-out self-selected bout was used to emulate 90% of maximal VO_2. A member of the research team monitored the eq02+ system during the HIIT and notified participants who were not reaching intended exercise intensities. Immediately following the acute exercise bout, C_2 commenced in the same fashion as C_1.

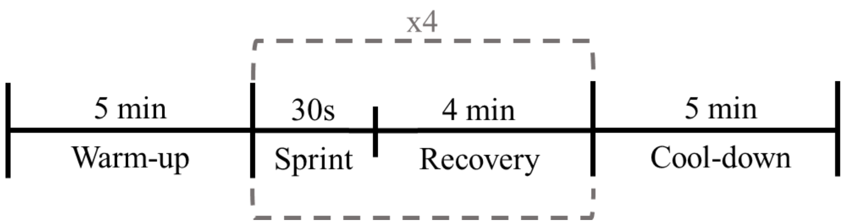


Figure 4. Acute HIIT protocol
Note: *HIIT,* High intensity interval training; *min*, minutes; *s*, seconds

Chronic Intervention

The chronic arm of the study was an eight-week period during which researchers instructed the control group to make no changes to their daily exercise habits. Participants in the exercise group completed an 8-week at home HIIT intervention. The researchers allowed the participant to self-select from the following list of exercise modalities: (1) stationary bike, (2) elliptical, (3) treadmill, (4) outdoor running, or (5) outdoor cycling. The video call application "Discord" was used for all communication during the chronic arm of the study. Discord is the primary form of social media used by SSBU players to communicate; and could be used via browser, desktop application, or mobile application. Prior to exercise the researcher re-explained the OMNI Scale to participants. The member of the research team who administered testing then re-explained that high intensity was a 9 out of 10 effort or emulated the second last stage they completed during VO_2 max testing. The researcher then explained that the active recovery phase should be a 6 out of 10 effort.

During week 1 of training each participant completed 4 self-selected high intensity bouts of exercise, each followed by a 4-minute recovery period at a self-selected pace. If participants owned an intensity tracking device, the researcher actively communicated with the participant during high intensity exercise and active recovery about their heart rate to ensure that participants were reaching desired intensities. If participants did not own an intensity tracking device, researchers utilized the “talk test [202].” During both high-intensity and active recovery the researcher instructed the participant to recite a standardized paragraph. The researcher asked the participants if they were able to speak comfortably. If the participant answered no or was unable to recite the paragraph, they were above 80% VO_2 max. If the participant was unable to recite the paragraph verbatim or answered that they were not sure if they could speak comfortably, they were at an appropriate intensity for active recovery. The researcher recorded the self-selected intensity during each bout of exercise. The speed of both the exercise and active recovery bouts gradually increased each session, the number of exercise bouts increased weekly by one during weeks 3-8 as displayed in Table 3.

Table 3 The eight-week HIIT protocol for exercise participants.

Note: *HIIT*, high intensity interval training; *HRR*, heart rate reserve *RPE*, rate of perceived exertion; *min*, minutes

Week	Format	Active Recovery	HIIT
1	4 HIIT; 4 active recovery	4 Min ≥ 60% HRR or ≥ 6/10 RPE	30s ≥ 90% HRR or ≥ 9/10 RPE
2	4 HIIT; 4 active recovery	4 Min ≥ 60% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
3	5 HIIT; 5 active recovery	4 Min ≥ 60% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
4	6 HIIT; 6 active recovery	4 Min ≥ 60% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
5	6 HIIT; 6 active recovery	4 Min ≥ 70% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
6	7 HIIT; 7 active recovery	4 Min ≥ 70% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
7	7 HIIT; 7 active recovery	4 Min ≥ 70% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
8	8 HIIT; 8 active recovery	4 Min ≥ 70% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE

Participants in each group were provided a packet to complete each week of the chronic intervention. During the eight-week intervention period participants logged weekly practice time, number of competitions entered, and time spent studying the game with intention to improve. After the eight-week intervention period participants competed in C_3 and C_4 in the same fashion as C_1 and C_2 respectively (I.e., no participants in either group exercised prior to C_3. Prior to C_4, participants in the exercise group repeated the acute exercise bout in the same fashion as prior to C_2). During C_3 and C_4, the same rules were used as the previous competitions. In all competitions researchers recorded each participant's number of set wins which were used as a metric for competitive eSport performance.

Researchers performed post-testing on all participants one week following C_4. Post-testing included the same tests as pre-testing, including: 1) body composition, 2) a manual Trails Task, 3) a digital Trails Task, and 4) a VO_2 max test. Body composition, Trails Task scores, and VO_2 max results were compared between pre and post-testing. Competitive eSport performance was compared both within and between groups across all competitions.

Statistical Analyses

Statistical Analyses were performed using R Studios version 3.0.1 (R Studio Team, Boston, MA, USA). Pearson Correlations were used to assess relationships between baseline skill, eSport performance scores at $C_{1,}$ and all pre-testing variables. Pearson Correlation was also used to assess the validity of the initial skill assessment by investigating the relationship between initial skill and performance at C_1. An r value between 0.0-0.1 was considered negligible, $0.1 \leq r < 0.39$ was considered weak, $0.39 \leq r < 0.69$ was considered moderate, $0.70 \leq r < 0.90$ was considered strong, and $0.90 \leq r \leq 1.00$ was considered very strong [203].

A Two-Way Repeated Measures analysis of variance (ANOVA) was used to assess differences in all pre-post test variables within and between groups. An *α priori* alpha level of 0.05 was used to determine statistical significance of effects. If significant interactions were evident for dependent variables, Bonferroni post-hocs were used to decompose the model and identify between and within-group significance.

Logistic regression analysis was used to assess if the exercise interventions increased the probability of a participant winning a set. An *α priori* alpha level of 0.01 was used to determine statistical significance of effects. A level of 0.01 was selected to help account for the violation of the assumption of independence by reducing the family-wise error likelihood. Three separate logistic regression models were constructed: 1) an acute exercise model, 2) a chronic endurance training model, and 3) a combination model.

The acute model was constructed to assess if the acute exercise intervention increased the probability of a participant winning a set. Thus, it modeled the probability of a participant winning at C_2 using group and score at C_1 centered around the mean as predictors. Group was used as a predictor to observe the effect of exercise. Mean win proportion at C_1 was used as a predictor because it served as a baseline score before any exercise interventions were implemented.

The chronic model was constructed to assess if the chronic endurance intervention increased the probability of a participant winning a set. Thus, it modeled the probability of a participant winning at C_3 using group and score at C_1 centered around the mean as predictors.

Lastly, the combination model was constructed to assess if the combined effects of acute exercise and the chronic endurance training program increased the probability of a participant winning a set. Thus, it modeled the probability of a participant winning at C_4 using group and score at C_1 centered around the mean as predictors. Log-odds ratios provided by the models were exponentiated for further interpretation.

Chapter IV

Acute High Intensity Interval Training Improves eSport Performance in Super Smash Brothers Ultimate Competitors

Introduction

Organized competitive video game play known as electronic sport (eSports) has recently made its way into peer reviewed literature. Scholars in multiple research fields have taken interest in eSport performance [18]. Research in cognitive and sport science attempts to determine which cognitive variables influence the success of the eSport athlete (E-athlete) [19-23] Attention, memory, information processing, and task-switching have been identified as possible cognitive functions which contribute to the success of the E-athlete [1, 24-29]. Playing action video games improves these cognitive functions, [24-27] and action video game players tend to score higher on test scores of these functions compared to non-gamers [28-31]. Furthermore, research into digital gaming competence suggests that E-athlete success is dependent on problem solving, visual attention, and working memory [32, 33].

Individuals achieve greater scores on tests of memory [43, 44], attention [45, 46], and task switching [48, 49] after an acute bout of cardiovascular exercise [47, 50-52]. Furthermore, highly fit participants tend to score higher on tests of cognitive functions than unfit participants of similar age and sex [53]. The same cognitive functions that are associated with E-athlete success also improve because of acute exercise and improved physical fitness. E-athlete physical activity data suggest that E-athletes self-report greater than one hour of physical activity per day, and most E-athletes believe that exercise improves their ability to succeed in competition [34, 35]. E-athlete physical activity data also suggest that E-athlete employers hire exercise specialists to help E-athletes maintain their physical fitness [34].The eSport performance literature points to a potential benefit of cardiovascular exercise on gaming performance [1, 18, 23, 34, 36]. Theoretical models of gaming competence indicate that attention, memory, and task-switching contribute to success in digital gaming [32, 33, 54]. These same areas improve after a bout of acute exercise. Furthermore, participants and eSport organizations seem to believe there is a positive effect of exercise on eSports performance, as evidenced by physical activity levels and training schedules of high level and professional E-athletes. However, no study to date has investigated the effect of an acute exercise intervention on E-athlete performance during competition.

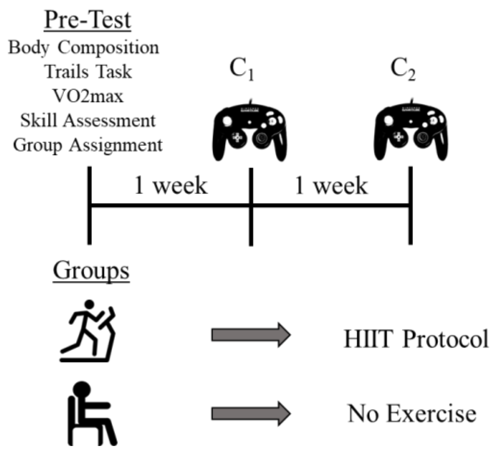
Therefore, the purpose of this study was to conduct the first experimental trial investigating the effects of cardiovascular fitness and acute cardiovascular exercise on eSport performance scores. Our hypotheses were three-fold: 1) there would be a positive linear relationship between baseline skill and baseline aerobic fitness in E-athletes; 2) a positive linear relationship between baseline skill and scores on tests of visuomotor performance would explain this relationship; 3) participants who completed a single bout of high-intensity interval training (HIIT) would achieve greater competitive eSport performance scores than a Control group.

Methods

Participants

Researchers recruited 28 active competitors in the Alabama Super Smash Brothers Ultimate (SSBU) community ages 17 – 25 (26 male (22 ± 2 years), 2 female (21 ± 1 years)). Participants were free from any injury, disease, or condition that would prevent them from participating in exercise or eSport competitions. Researchers obtained written informed consent from each participant prior to any testing. All protocols were approved by the Auburn University Institutional Review Board (Protocol#21-350).

Study Design



Competition; Exercise group; Control group

Figure IV-1. Acute Intervention Study Design

A 2 x 2 [group (Control, Exercise) and time (C_1, C_2)] design was implemented in this study. Body composition, maximal aerobic power (VO_2 max) , visuomotor performance, and eSport performance were assessed through bioelectric impedance analysis [198], Trails A and B Tasks [199], open circuit spirometry and a treadmill Bruce Protocol, [200] and SSBU competition results; respectively. eSport performance was assessed at C_1 and C_2. Physiological and cognitive variables were assessed during baseline testing.

Body Composition

Researchers determined body composition [body fat % (BF%)] of each participant using the SFB7 bioelectrical impedance spectroscopy analyzer (Impedimed; Pinkenba, Queensland Australia). Participants arrived at body composition testing 12 hours abstained from alcohol and caffeine. Researchers conducted a urine specific gravity test via portable refractometer (V-Resourcing, Hunan, China) to ensure participants were hydrated. Researchers deemed participants were hydrated if urine specific gravity value was below 1.025. If participants were not hydrated, they were provided with 16 fl. oz of water. After a 15-minute hydration period, the participants were re-assessed for hydration status. This was repeated until the participant was properly hydrated.

Trails Task

The Trails A and B Tasks measured cognitive function via visuo-motor performance. Trails A and B were completed in the fashion described in previous literature [199]. All Trails Tasks were conducted by the same researcher, using the same script, in a room free from any visual or auditory distractions. The researcher conducting the Trails Tasks did not wear any distracting clothing or jewelry. Both Trails Tasks consisted of an eight-item example followed by a 25-item timed trial. Researchers reported the switch cost score as the difference in time to completion for Trails A and B.

VO_2 Max Testing

A VO_2 max test was used to determine maximal aerobic power utilizing the graded treadmill Bruce Protocol [200] outlined in Table 1. Pulmonary gas exchange was measured using open circuit spirometry and a metabolic cart (Parvomedics, Salt Lake City, Utah). Participants were outfitted with an eq02+ Life Monitor (equiVital, Cambridge, UK) for observation of heart rate during the maximal test.

Tests were considered valid if one of the following criteria were met in addition to voluntary termination: (1) respiratory exchange ratio $\geq$ 1.15; (2) a plateau in oxygen consumption determined by a change lower than 100 $ml \cdot min^{-1}$ in the last 30 s of the previous stage; or (3) a heart rate within 10 $beats \cdot min^{-1}$ of the age-predicted heart rate max (220-age). Each participant's peak oxygen consumption and total time to exhaustion (TTE) were recorded.

Researchers used a modified OMNI (omnibus) Scale [204] (0-10) during VO_2 max testing as a measurement of perceived effort (Table 2).

Table IV-1. Bruce protocol graded exercise treadmill test for VO_2 max.
Note: *min*, minutes; *mph*, miles per hour

Stage	Duration (min)	Speed (mph)	Grade (%)
1	3	1.7	10
2	3	2.5	12
3	3	3.4	14
4	3	4.2	16
5	3	5	18
6	3	5.5	20
7	3	6	22

Table IV-2. Modified OMNI Scale

Perception of Effort	Description
0	No effort; "You are lying down doing nothing"
1	
2	Easy
3	
4	Somewhat easy
5	
6	Somewhat difficult
7	
8	Difficult
9	Extremely difficult; "Maximal Effort"
10	Stop test immediately

Initial Skill Assessment

All participants compete regularly in offline double elimination SSBU tournaments outside of the study. Results from all tournaments are recorded in the Smash Data section of the PGStats website (Panda Global, Detroit, MI, USA). Researchers utilized the names that participants used while competing in tournaments outside of the study to retrieve tournament results for each participant eight weeks prior to the first eSport data collection. Participant skill was determined by their results in tournaments (expressed as a percentile) during the eight weeks prior to data collection.

Groups Assignment

After pre-testing, researchers matched participants into pairs based on game skill (described above) and baseline VO_2 max. A member of the research team with no personal relationship to the participants randomly assigned one participant from each matched pair to either the Exercise or Control group so that n = 14 for each group.

Competitions

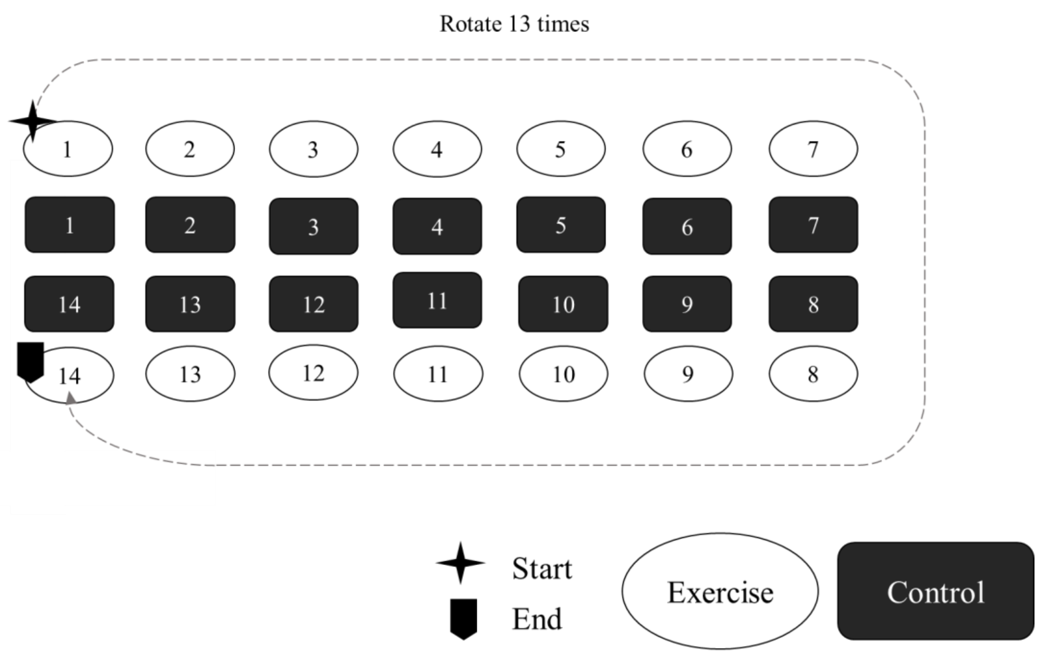


Figure IV-2. Competition format. Numbers represent individual participants at gaming stations. Exercise participants (numbers in ovals) rotated left, the participants in the Control group remained stationary.

Each gaming setup consisted of a Nintendo Switch, (Nintendo, Kyoto, Japan), and a copy of SSBU. Participants brought personal controllers to every competition. SSBU is a platform fighting game with two competitors playing one versus one on an agreed upon map with three lives. Both competitions in this study utilized the unified Alabama SSBU ruleset: 1) three lives, 2) seven-minute time-limit, and 3) standard map-list. The objective was to eliminate all three of the opponent's lives. The participant who eliminated all three of their opponent's lives first won the game. The first participant to win two games won the set. The two competitions are labeled C_1 and C_2 (refer to Figure 1). At the conclusion of C_1, participants filled out a short 24-hour sleep, practice time, and substance use recall. The participants were asked to emulate sleep and practice time patterns prior to C_2.

Acute Intervention

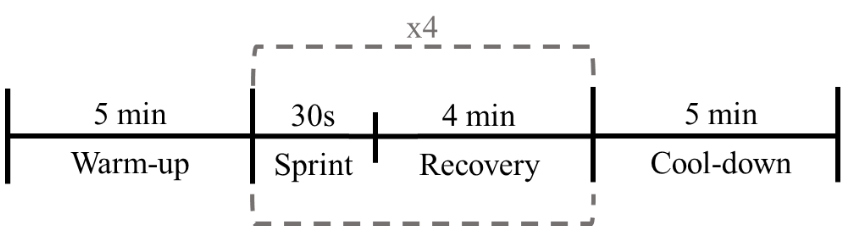


Figure IV-3. Acute HIIT protocol

Note: *HIIT*, High intensity interval training; *min*, minutes; *s*, seconds

For every competition, all participants arrived abstained from exercise for 24 hours. Researchers recorded total set wins for each participant during each competition. Participants returned to complete C_2 seven days after C_1. At C_2 the Control group participants gathered for 30 minutes before competition in which they were permitted to do any activity except exercise or play SSBU. Participants in the Exercise group met with a member of the research team to simultaneously complete a bout of high intensity interval training (HIIT) (Figure 3). Researchers fit each participant with an eq02+ Life Monitor (equiVital, Cambridge, UK) to monitor heart rate. The participants completed four bouts of 30 second sprint intervals (nine on OMNI Scale) with four-minute active rest intervals (six on OMNI Scale) between each bout. This is a modification of a protocol used in a cycle-ergometer HIIT study [175]. C_2 commenced in the same fashion as C_1 (described in Figure 2) immediately following the acute exercise bout.

Statistical Analyses

Statistical Analyses were performed using R Studios version 3.0.1 (R Studio Team, Boston, MA, USA). Pearson Correlations were used to assess relationships between baseline skill, eSport performance scores at C_1, and all pre-testing variables. Pearson Correlation was also used to assess the validity of the initial skill assessment by investigating the relationship between initial skill and performance at C_1. An r value between 0.0-0.1 was considered negligible, $0.1 \leq r < 0.39$ was considered weak, $0.39 \leq r < 0.69$ was considered moderate, $0.70 \leq r < 0.90$ was considered strong, and $0.90 \leq r \leq 1.00$ was considered very strong [203].

Logistic regression analysis was used to assess if the acute HIIT intervention increased the probability of a participant winning a set at C_2. An *α priori* alpha level of 0.01 was used to determine statistical significance of effects. Log-odds ratios were exponentiated for further interpretation. Mean win proportion at C_1 was used as a predictor because it served as a baseline score when neither group exercised. Group was used as a predictor to assess the effect of acute HIIT on performance at C_2. The logistic regression analysis provided the odds that a participant would win at C_2 assuming they did not win a single set at C_1. The logistic regression model was centered around the mean win proportion at C_1 so that the exponentiated intercept log-odds could be interpreted to mean "the percent chance that a member of the Exercise group would win, assuming their win % at C_1 was 50%.

Results

Baseline descriptive statistics for each group are displayed in Table 3. There were no significant differences between groups for any pre-test measurement ($p \geq 0.05$).

Table IV-3. Baseline descriptive statistics.

VO_2, oxygen consumption; *TTE* Time to exhaustion; *BMI*, Body mass index

	Exercise (n = 14)	***Control (n = 14)***	***t-value (df)***	***p***
Average placement (percentile)	58.78 ± 22.26	57.36 ± 23.11	0.17 (26)	0.87
Set win rate (%)	48.82 ± 21.61	47.75 ± 21.62	0.13 (26)	0.89
Game win rate (%)	47.90 ± 16.63	48.11 ± 18.31	-0.03 (26)	0.97
VO_2 Max ($ml \cdot kg^{-1} \cdot min^{-1}$)	40.81 ± 6.9	41.54 ± 8.81	-0.24 (26)	0.81
TTE (s)	753.29 ± 78.30	772.21 ± 111.06	-0.52 (26)	0.61
BMI	27.79 ± 6.04	25.58 ± 7.46	0.86 (26)	0.39
Body fat (%)	29.65 ± 8.82	23.37 ± 9.46	1.82 (26)	0.08
Trails A (s)	22.00 ± 9.17	24.14 ± 8.42	-0.64 (26)	0.52
Trails B (s)	48.14 ± 16.79	51.5 ± 17.26	-0.52 (26)	0.60
Switch cost (s)	25.57 ± 16.70	26.57 ± 18.29	-0.15 (26)	0.88

Table 4 details correlations between baseline testing scores and baseline VO_2 max. Table 5 details correlations between baseline testing scores and eSport performance scores at C_1.

Table IV-4. Correlational data describing relationships between baseline testing variables and average placement in double elimination events eight weeks prior to the study.

BMI, Body mass index; *VO_2,* oxygen consumption; *TTE* Time to exhaustion

Variable	Pearson's R	Direction; Strength
VO_2 max	0.03	Negligible
TTE	0.01	Negligible
BMI	-0.09	Negligible
Body fat (%)	-0.15	Negative; Weak
Trails A	0.39	Positive; Moderate
Trails B	-0.22	Negative; Weak
Switch cost	-0.44	Negative; Moderate

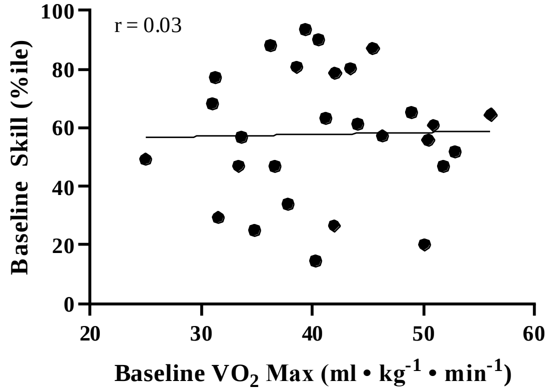
Table IV-5. Correlational data describing relationships between baseline testing variables and performance at C_1. Performance at C_1 was expressed as a proportion of accumulation of wins to the number of total sets played.

BMI, Body mass index; *VO_2,* oxygen consumption; *TTE* Time to exhaustion

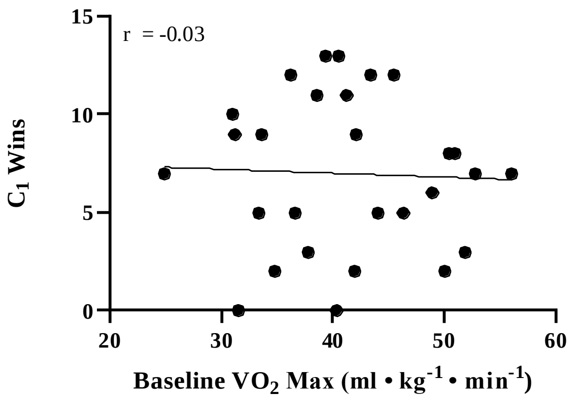
Variable	Pearson's R	Direction; Strength
VO_2 max	-0.03	Negligible
TTE	0.09	Negligible
BMI	-0.11	Negative; Weak
Body fat (%)	-0.01	Negligible
Trails A	0.39	Positive; Moderate
Trails B	-0.15	Negative; Weak
Switch cost	-0.38	Negative; Weak

There was a negligible correlation between baseline VO_2 max and the initial skill assessment ($r = 0.03$) or scores at C_1 ($r = -0.03$) (Figure 4). There was a strong direct correlation between the Initial Skill Assessment and scores at C_1 ($r = 0.933$) (Figure 4).

a)



b)



c)

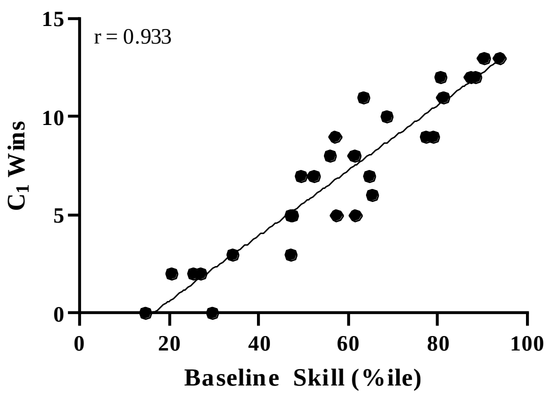


Figure IV-4. Correlational data assessing relationships between: a) baseline skill and VO_2 max; b) C_1 wins and VO_2 max; and c) C_1 wins and baseline skill.

Note: C_1 wins indicate the total wins accumulated at the first competition. Baseline skill (expressed as a percentile) was determined by average results in double elimination brackets for eight weeks prior to the study.

The logistic regression model indicates a significant effect of group for improving odds that a participant will win at C_2. ($p = 0.00672$, log-odds ratio = 0.7178, exp = 2.049918) (Table 6). Group mean wins at timepoints C_1 and C_2 are displayed in Figure 5.

Table IV-6. Logistic regression data for the Acute Intervention. Performance at C_1 was expressed as a proportion of accumulation of wins to the number of total sets played. * Indicates a significant effect ($p \leq 0.01$).

Note: *CI*, Confidence interval

C_1 | C_2	Log-odds	Exp(log-odds)	P value	2.5% CI	97.5% CI
Intercept	-0.3850	0.680450	0.03618 *	-0.7498	-0.02775
C_1 Win	4.8619	129.2696	2e-16 *	3.7781	6.05330
Group	0.7178	2.049918	0.00672 *	0.2055	1.24621

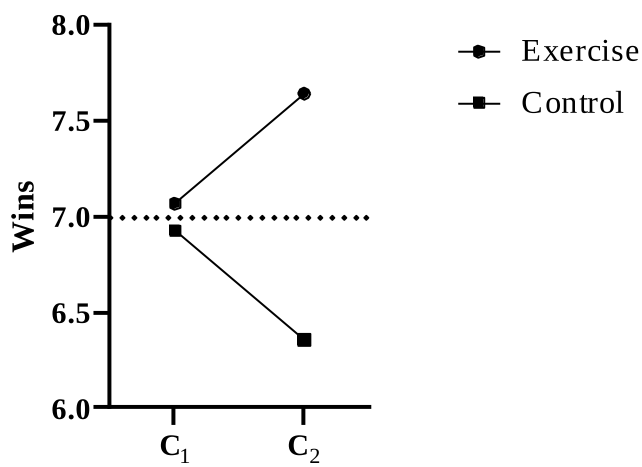


Figure IV-5. Visualization of group win means at C_1 and C_2. Wins indicate the total accumulation of wins at each timepoint. At C_1, neither group exercised. At C_2, the Exercise group completed an acute HIIT bout immediately before eSport competition.

Discussion

The purpose of this study was to determine the effect of a single 30-minute bout of HIIT on eSport performance scores in SSBU competitors. VO_2 max and Trails Task data were collected to assess if baseline skill or performance could be explained by these physiological or cognitive variables. Performance was measured by a proportional win rate in semi-round robin style SSBU competitions. A logistic regression model was then constructed to assess the effect of the acute intervention by comparing results at C_1 and C_2. Comparisons at baseline indicate that groups were evenly matched in terms of both skill and fitness level. Furthermore, participants did not make changes to sleep patterns or practice time, and the amount of video game warm-up was controlled for each group. In this sense, any changes in performance between timepoints could be explained by the acute exercise intervention.

The primary finding of this study is that a single, 30-minute bout of HIIT exercise immediately prior to eSport competition improves the odds that a competitor will win. All competitors who were unable to win at C_1 had a 6% chance of winning a set at the following timepoint. The exponentiated log-odds (2.04) indicate that this chance of winning would double to 12% following acute exercise. The increased odds of a participant winning a set at C_2 after acute exercise may be the result of the effects of acute exercise on cognitive performance. The findings of our study support a great deal of prior work suggesting that acute exercise prior to tests of cognitive performance yields positive results [47, 50, 52].

Multiple theories of game competence suggest that improvements in cognition would be the vehicle for improvements in eSport performance [32, 33]. Existing research recognizes the role specifically of task-switching in this process. Therefore, our study makes a major contribution to the existing body of research by demonstrating that participants who completed a single 30-minute bout of HIIT improved eSport performance scores.

Additional findings from our study include: 1) the lack of relationship between baseline skill level and fitness; and 2) the lack of a relationship between baseline skill level and visuomotor performance. VO_2 max means at baseline (Exercise; 40.81 ± 6.9: Control; 41.54 ± 8.81) for both groups were comparable to normative data for all genders of a similar age range (men; 44.2 ml · kg^{-1} · min^{-1}; women: 37.8 ml · kg^{-1} · min^{-1}) [205]. This indicates that average fitness levels of E-athletes may not differ from non-gamers of similar age and sex. This finding may help to alleviate E-athlete stereotypes relating to poor health and fitness. Interestingly, results from previous survey literature in E-athletes indicate that E-athletes exceed physical activity recommendations for the general population (self-reported 1.08 hour daily average) [34, 35]. Our results indicate that although some E-athletes may exceed general physical activity recommendations, their activity level is not indicative of greater cardiovascular fitness. However, further inspection of our VO_2 max data reveals that cardiovascular fitness may not impact eSport performance. The section below critically assesses the concept of cardiovascular fitness and eSport performance.

The negligible relationship between VO_2 max and eSport performance at double elimination events preceding the study ($r = -0.03$) was surprising. This functions as a rejection of our hypothesis that there would be a positive linear relationship between fitness level and skill. This rejection is reinforced by results at C_1 indicating no relationship between VO_2 max and eSport performance scores at C_1 ($r = -0.03$). The results of our cross-sectional data indicate no evidence of the effect of maximal oxygen consumption on eSport performance. Findings from previous literature suggests that highly fit participants perform better on tests of cognitive function than their low-fit counterparts [53]. As such, we formed our hypothesis under the assumption that participants with greater cardiovascular fitness would demonstrate greater cognitive performance, and that would in turn be the mechanism for greater practical eSport performance. However, our cognitive data do not support that conclusion. Therefore, an additional finding of our study is that fitness level in the eSport athlete population may not be related to performance on the Trails Tasks.

Visuomotor performance, as measured by Trails A and B, in both groups were comparable to means of normative data in high-school educated people ages 18-24 (Trails A: 22.93 ± 6.87s; Trails B: 48.97 ± 12.96s) [199]. This contradicts findings from previous literature that action video game players tend to score higher on tests of cognitive function [29-31]. Our cognitive results include three additional interesting findings. Our primary finding was the positive, moderate relationship between Trails A and performance at C_1. This indicates that players with high performance scores took longer to complete Trails A. In addition, there was a negative, moderate relationship between switch cost and performance at C_1. This implies that although the high performing players took longer to complete Trails A, they demonstrated greater cognitive flexibility. Our third and final finding concerning the Trails Data is that both relationships were mimicked when assessing correlations between Trails scores and baseline skill. The baselines skill is assessed using tournament results outside of the study. The third finding indicates that not only is there a relationship between Trails scores and acute eSport performance in competition, but also a relationship between Trails scores and player ranking. Overall, the findings suggest that players of higher skill level took longer to complete Trails A but had a smaller difference in time to completion between A and B. While the negative relationship between switch cost and performance confirms our hypothesis that skill would be directly related to visuomotor performance, the positive relationship between time to completion for Trails A and performance contradicts it. One possible explanation for these findings is that the objective of the Trails Task A does not align with the specific eSport studied (SSBU).

The Trails Tasks were timed tests, meaning that the goal of the tests was to complete them as quickly as possible [199]. If a participant made a mistake, the researcher guided them to last point in the Task where they were correct. The researchers observed that making a mistake on the Trails A side often was far less consequential that making a mistake on the Trails B side. The Trails A side consists of only numbered items, while the Trails B side consisted of both number and letter items. When a participant made a mistake on the Trails A side, they were able to pick up from their last correct point more quickly. Conversely, when a participant made a mistake on the B side, the researchers observed that some of the participants were slow to recover. While SSBU has a time-limit, winning is not achieved by accomplishing the goal as quickly as possible. Instead, it is achieved by taking whatever action is necessary within game to outplay the opponent and eliminate their three lives. There has never been an analysis between win rate percentage and SSBU playstyle. However, it is often observed in eSport competitions that a playstyle centered around minimizing mistakes is the most effective. This may explain the inconsistency in the Trails relationships to performance. Perhaps, the Trails A side rewarded participants who focused solely on speed to complete the task, while the Trails B side (and subsequently switch cost) rewarded those who emphasized making as few mistakes as possible. However, we did not record number of mistakes made during the Trails Tasks, nor did we take specific notes on participant playstyle during the eSport competitions. Future research should consider both measurements if they choose to observe relationships between SSBU competition performance and Trails Task. Alternatively, future researchers may conclude that the Trails Tasks are not appropriate tests of cognitive performance specifically for the SSBU population and will decide to utilize different cognitive tests.

Limitations to our study include participant motivation and a lack of cognitive reassessment after acute exercise. SSBU features over 80 playable characters used in competition. Typically, a SSBU competitor will play one character during tournaments. This character is colloquially referred to as their main. SSBU competitors practice other characters which they play casually. These characters are called their secondaries. At timepoint C_2, five (3 Control, 2 Exercise) of the participants played secondaries. Further investigation into their competition data outside the study indicates that all five competitors who played secondaries had never played those characters in a competitive setting. This likely had a negative impact on their results. Future studies in this area may consider requiring participants to play the same characters at each timepoint to combat the potential for a sudden decrease in performance unrelated to any interventions. Some participants vocalized that since the study did not affect their rankings on a state or national scale, even though they were compensated for study participation they were not incentivized to try to win. Future studies in this area may consider working with local tournament organizers to establish a separate ranking system that includes results from the study. Lastly, we did not assess cognitive measures immediately after exercise. Researchers in future studies should consider a study design where assessment of Trails or other cognitive tests occurs in all participants immediately following an acute exercise bout.

Conclusion

This study was the first to observe the direct effects of acute exercise on competitive eSport performance scores. Results indicate a positive effect of acute exercise on eSport performance in SSBU competitors. Future work should include larger sample sizes and re-assessment of cognitive performance after acute exercise.

Chapter V

A Combination of Acute High Intensity Interval Training and an Eight-Week HIIT Protocol improves eSport Performance Scores in Super Smash Brothers Ultimate Competitors

Introduction

Scholars in multiple fields of research have taken an interest in video games due to their rise in popularity [1]. Video game researchers have explored the consequences of violent video games [2-4], the potential health consequences of gaming and video game addiction [5-7], and how the integration of physical activity into video games might combat health pitfalls associated with the sedentary nature of gaming [8-10]. Additional research in gaming has investigated the use of virtual reality to provide safe simulations in multiple careers (e.g., flight simulation, surgery, and sport) [11-13] and the use of video games to improve cognitive functions in children with learning disabilities [14, 15]. In sum, a large body of gaming literature examines the use of a popular recreational activity on improvements to activities of daily living and job performance. However, gaming recently evolved from a juvenile recreational activity into an avenue for organized competition known as electronic sport (eSports).

Scholars in the fields of cognition and sports science have taken an interest in eSport performance research due to the rise in eSport popularity and potential for financial gain [18]. eSports performance scholars have begun an attempt to answer the question “Which cognitive variables contribute to success in eSports?” [19-23] Cognitive research identifies the primary determinants for success in digital gaming as: 1) visual attention, 2) short-term and working memory, and 3) task-switching [1, 24-29]. Cognitive performance improves as a result of video game interventions [24-27], or is higher in gamers as indicated by scores on tests of cognitive performance [28-31]. Results from these studies align with multiple theoretical frameworks of gaming competence, which suggest that success in digital gaming relies on a problem-solving mind with a focus on attention and memory [32, 33].

Exercise science research indicates that cardiovascular exercise improves cognitive performance [36-42]. Specifically, individuals achieve greater scores on tests of memory [43, 44], attention [45, 46], and task switching [48, 49] after an acute bout of cardiovascular exercise [47, 50-52] or as the result of participation in an endurance training program [37, 40, 41]. Furthermore, highly fit individuals tend to achieve higher scores on tests of these cognitive variables when compared to low-fit counterparts [53]. In sum, the same cognitive areas which determine success in digital gaming all improve because of cardiovascular exercise.

Results from a series of qualitative studies inquiring about physical activity suggest that eSport athletes (E-athletes) exceed physical activity recommendations for the general population (self-reported 1.08 hour daily average), and more than 50% of E-athletes believe that physical activity improves their performance [34, 35]. Researchers also reported that professional eSport organizations hire personal trainers to design exercise training regimens for their E-athletes [34].

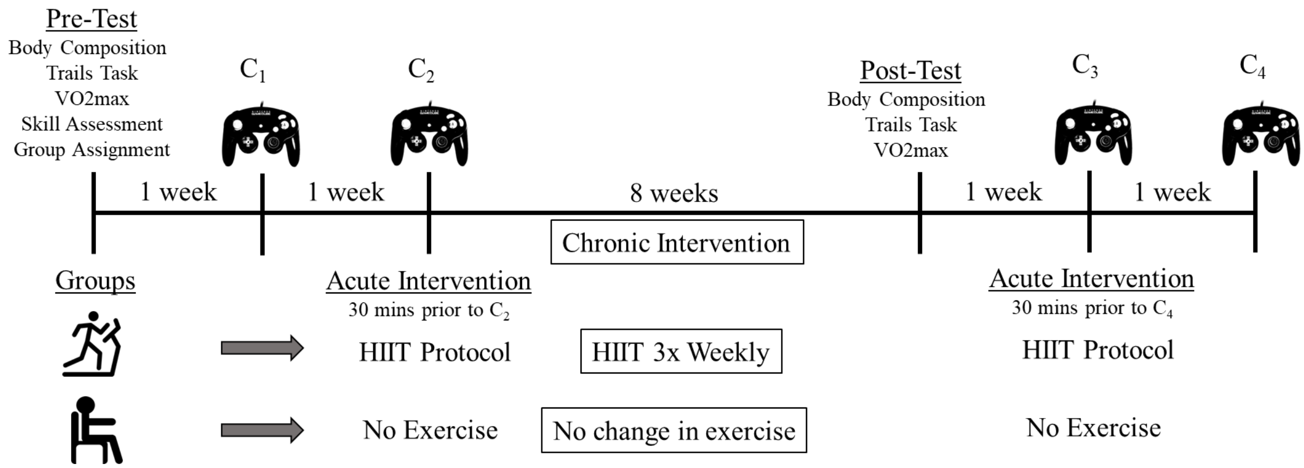
The relationship between cardiovascular exercise and cognitive functions associated with success in digital gaming suggests a clear potential benefit of aerobic activity on eSport performance. However, no study to date has observed the effect of an exercise intervention on E-athlete performance during competition. Therefore, the purpose of this study was to conduct an experimental trial investigating the acute and chronic effects of cardiovascular exercise on competitive eSport performance scores. Our hypotheses were three-fold: 1) there would be a positive linear relationship between baseline skill and baseline aerobic fitness; 2) participants who complete a single bout of high-intensity cardiovascular exercise will achieve greater competitive eSport performance scores when compared to a non-exercising Control group; and 3) participants who complete a prescribed eight-week endurance training program will experience greater improvements in competitive eSport performance scores when compared to a non-exercising Control group.

Methods

Participants

Researchers recruited 26 active competitors in the Alabama Super Smash Brothers Ultimate (SSBU) eSport community ages 17 – 25 (24 male (20.6 ± 2.27), 2 female (21 ± 1)). Participants were free from any impairments or conditions that would preclude them from safely and effectively participating in exercise or gaming. Researchers obtained written informed consent from each participant prior to any testing. All protocols were approved by the Auburn University Institutional Review Board (Protocol#21-350).

Study Design



Competition; Exercise group; Control group

Figure V-1. Study Design

A 2 x 4 [group (Control, Exercise) and time (C_1-C_4)] repeated measures design was implemented in this study. The dependent variables of body composition, maximal aerobic power (VO_2 max), visuomotor performance, and eSport performance were assessed through bioelectric impedance analysis [198], Trails A and B Tasks [199], open circuit spirometry and a treadmill Bruce Protocol, [200] and SSBU competition results respectively. eSport performance was assessed at four timepoints (C_1 – C_4). Remaining variables were assessed during pre- and post-testing.

Body Composition

Researchers determined body composition (fat mass and BMI) of each participant using the SFB7 bioelectrical impedance spectroscopy analyzer (Impedimed; Pinkenba, Queensland Australia). Participants abstained from caffeine, alcohol, and exercise for 12 hours prior to testing. Researchers conducted a urine specific gravity test via portable refractometer (V-

Resourcing, Hunan, China) to ensure participant hydration status. Participants were considered hydrated if urine specific gravity value was below 1.025. If participants were not hydrated, they were instructed to consume water and were reassessed until they were fully hydrated.

Trails Task

The Trails Task A and B were used as a measurement of visuo-motor performance. Trails A and B were completed in the method described in previous literature [199]. Both Trails A and B consisted of an eight-item practice followed by a 25-item timed trial. Researchers reported the switch cost score as the difference in time to completion for Trails A and B. Switch cost is the primary visuomotor performance variable and a metric of task-switching.

VO_2 Max Testing

A VO_2 max test was used to determine maximal aerobic power utilizing the graded treadmill Bruce Protocol [200]. Participants began the protocol with a one minute warm up at 1.7 mph and 0% incline. At the conclusion of the warm-up testing began starting at stage one. Every three minutes the speed and grade of the treadmill increased according to Table 1. Pulmonary gas exchange was measured using open circuit spirometry and a metabolic cart (Parvomedics, Salt Lake City, Utah USA). Participants were outfitted with an eq02+ Life Monitor (equiVital, Cambridge, UK) for live monitoring. Tests were considered valid if one of the following criteria were met in addition to voluntary termination: 1) respiratory exchange ratio $\geq$ 1.15; 2) a plateau in oxygen consumption determined by a change lower than 100 ml $\cdot$ min^{-1} in the last 30 s of the previous stage; or 3) a heart rate within 10 beats $\cdot$ min^{-1} of the age-predicted maximal heart rate (220-age). Each participant's peak oxygen consumption and total time to exhaustion (TTE) were recorded. Researchers used an OMNI Scale (0-10) during VO_2 max testing as a measurement of perceived effort [204]. An answer of zero was interpreted as no effort, a nine as maximal effort, and a 10 indicated that the researchers needed to stop the test immediately.

Table V-1. The Bruce protocol graded exercise treadmill test for VO_2 max.
Note: *min*, minutes; *mph*, miles per hour

Stage	Duration (min)	Speed (mph)	Grade (%)
1	3	1.7	10
2	3	2.5	12
3	3	3.4	14
4	3	4.2	16
5	3	5	18
6	3	5.5	20
7	3	6	22

Table V-2. Modified OMNI Scale

Perception of Effort	Description
0	No effort; "You are lying down doing nothing"
1	
2	Easy
3	
4	Somewhat easy
5	
6	Somewhat difficult
7	
8	Difficult
9	Extremely difficult; "Maximal Effort"
10	Stop test immediately

Initial Skill Assessment

All participants compete regularly in SSBU tournaments outside of the study. Results from these tournaments are recorded in a public database in the data section of the PGStats website (Panda Global, Detroit, MI, USA). Participant skill was determined by their results in tournaments (expressed as a percentile) during the eight weeks prior to data collection.

Groups Assignment

Researchers matched participants into pairs based on game skill (as described above) and baseline VO_2 max determined from baseline pre-testing. One participant from each matched pair was randomly assigned to either the Exercise or Control group so that n = 13 for each group by a research team member who did not know the participants

Competitions

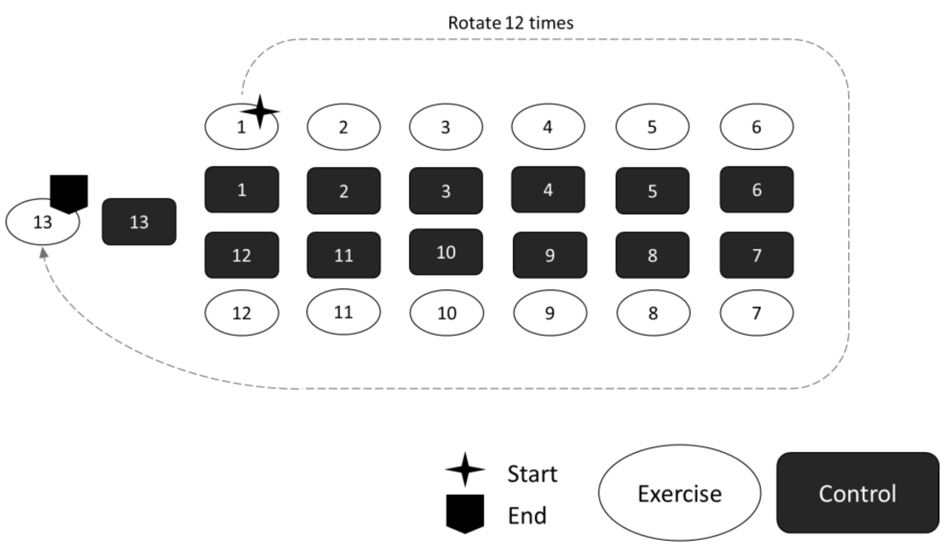


Figure V-2. Competition format. Numbers represent individual participants at gaming stations. Exercise participants (numbers in ovals) rotated left, the participants in the Control group remained stationary.

Each gaming setup consisted of a Nintendo Switch and Switch Dock (Nintendo, Kyoto, Japan), gaming monitor with at least 60 hertz refresh rate, and a copy of SSBU for the Nintendo Switch. Participants used their personal controllers at every competition. SSBU is a platform fighting game with two competitors playing each other using an agreed upon map (called a stage). Each player starts with three lives (called stocks). Every competition in this study utilized the unified Alabama SSBU ruleset: 1) three stocks, 2) seven-minute time-limit, and 3) standard stage-list. The objective was to eliminate all three of the opponent's stocks. The participant who eliminated all three of their opponent's stocks first won the game. The first participant to win two games won the set. Four competitions were completed for this study, labeled C_{1-4} respectively (Figure 1). The semi-round robin competition style is diagramed in Figure 2. The study competitions began by each member of the Exercise group playing a set against a member of the Control group. When the first set was completed, all Exercise group competitors rotated left to play against the next participant in the Control group. This process was repeated until each member in the Exercise group played a set against each member of the Control group once.

Acute Intervention

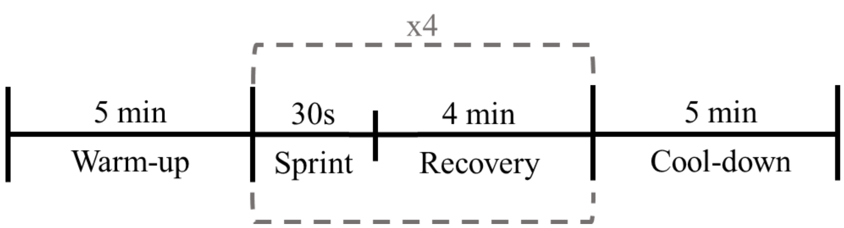


Figure V-3. Acute high intensity interval training (HIIT) protocol

Note: *min*, minutes

All participants abstained from exercise for 24 hours prior to arrival at all competitions. Researchers recorded total set wins for each participant during the C_1 competition. One week following C_1, participants returned for C_2. Researchers first fit each participant with an eq02+ Life Monitor (equiVital, Cambridge, UK) heart rate monitor to track heart rate reserve. Prior to C_2 the Control group participants gathered 30 minutes before competition. They were permitted to do any activity except exercise or play video games for 30 minutes. Participants in the Exercise group met with researchers 30 minutes prior to C_2 to complete a bout of HIIT (Figure 3). Participants completed four bouts of 30 second all-out sprint intervals (nine on the OMNI Scale or 90% of heart rate reserve) and four-minute active rest intervals (six on the OMNI Scale or 60% of heart rate reserve) between each bout. This exercise protocol was adapted from a cycle-ergometer protocol used in a sprint interval training study [175]. Immediately following the acute exercise bout, C_2 commenced in the same fashion as C_1.

Chronic Intervention

Following C_2 participants in the Exercise group began an eight-week chronic exercise intervention. Control group participants were instructed to make no changes to their daily exercise habits. Participants in the Exercise group completed an eight-week at home HIIT intervention. Participants self-selected from the following list of exercise modalities: 1) stationary bike, 2) elliptical, 3) treadmill, 4) outdoor running, or 5) outdoor cycling. Virtual monitoring via the Discord ® social media platform was used for all communication during the chronic arm of the study. Every exercise session for every participant was supervised by a member of the research team. During week one of training each participant completed four high intensity bouts of exercise at a self-selected intensity based on heart rate reserve and perceived exertion, each followed by a four-minute recovery period at a self-selected pace. Exercise intensity was measured utilizing a Fitness Tracker (Fitbit, San Francisco, CA, USA). The speed of the HIIT and active recovery bouts and the number of exercise bouts increased gradually each week as outlined in Table 3. All workouts were preceded by a five-minute warm-up and concluded with a five-minute cooldown at $\geq$ 50% HRR or $\geq$ 5/10 RPE.

Table V-3 The eight-week HIIT protocol for Exercise group participants.

Note: *HIIT*, high intensity interval training; *HRR*, heart rate reserve *RPE*, rate of perceived exertion *min*, minutes

Week	Format	Active Recovery	HIIT
1	4 HIIT; 4 active recovery	4 Min ≥ 60% HRR or ≥ 6/10 RPE	30s ≥ 90% HRR or ≥ 9/10 RPE
2	4 HIIT; 4 active recovery	4 Min ≥ 60% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
3	5 HIIT; 5 active recovery	4 Min ≥ 60% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
4	6 HIIT; 6 active recovery	4 Min ≥ 60% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
5	6 HIIT; 6 active recovery	4 Min ≥ 70% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
6	7 HIIT; 7 active recovery	4 Min ≥ 70% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
7	7 HIIT; 7 active recovery	4 Min ≥ 70% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE
8	8 HIIT; 8 active recovery	4 Min ≥ 70% HRR or ≥ 6/10 RPE	45s ≥ 90% HRR or ≥ 9/10 RPE

After the eight-week intervention participants competed in C_3 and C_4 in the same fashion as C_1 and C_2 respectively. In all competitions researchers recorded each participant's number of set wins. Proportion of accumulated wins to total sets played was used as the metric for eSport performance at each competition (i.e., If a participant won four sets, their eSport performance score was calculated as 4/13 = 0.307).

Researchers scheduled post-testing for all participants one week following C_4. Post-testing included the same tests as pre-testing. Body composition, Trails Task scores, and VO_2 max results were compared between groups pre- and post-testing. Competitive eSport performance was compared both within and between groups across all competitions.

Statistical Analyses

Statistical analyses were performed using R Studios version 3.0.1 (R Studio Team, Boston, MA, USA). Pearson correlation was used to assess the relationship between baseline fitness and game skill. Pearson correlation was also used to assess the validity of the initial skill assessment by investigating the relationship between initial skill and performance at C_1. An r value ≥ 0.9 was used to indicate a very strong correlation.

A two-way repeated measures analysis of variance (ANOVA) was used to assess differences in all pre- to post-test variables within and between groups. An *α priori* alpha level of 0.05 was used to determine statistical significance of effects. If significant interactions were evident for dependent variables, Bonferroni post-hoc analyses were used to decompose the model and identify between and within-group significance.

Logistic regression analysis was used to assess if the exercise interventions increased the probability of a participant winning a set. An *α priori* alpha level of 0.01 was used to determine statistical significance of effects. Three separate logistic regression models were constructed: 1) an acute exercise model, 2) a chronic endurance training model, and 3) a combination model. Log-odds ratios provided by the models were exponentiated for further interpretation. Mean win proportion at C_1 was used as a predictor because it served as a baseline score before any exercise interventions were implemented. Group was used as a predictor to assess the effect of exercise.

Results

There were no significant differences between groups for any pre-test measurement ($p \geq 0.05$). There were no significant differences between groups for any post-test measurement ($p \geq 0.05$). There was an effect of time for Trails Task A side ($p = 0.037$), B side ($p = 0.003$) and switch cost ($p = 0.048$) scores in both groups.

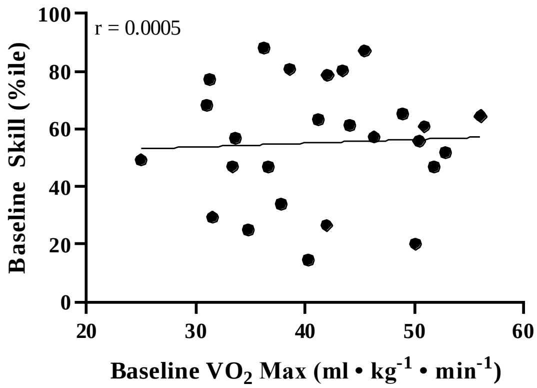
Table V-4. Pre and post-test values of all physiological and cognitive variables. # Indicates a significant effect of time.

Note: *VO_2,* oxygen consumption; *TTE,* time to exhaustion; *BMI*, body mass index, *ml,* milliliters; *min*, minutes; *s*, seconds

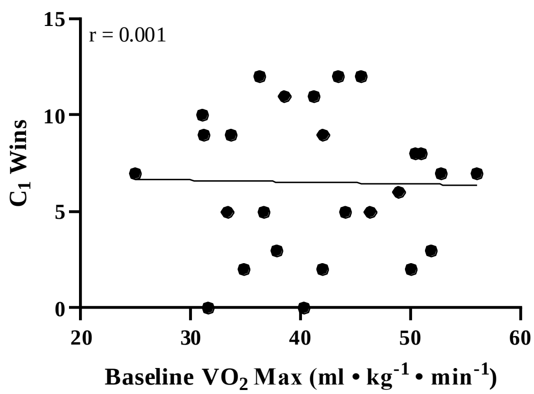
	Exercise (n = 13)		*Control (n = 13)*	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$)	40.93 ± 7.18	41.97 ± 7.39	41.62 ± 9.17	41.32 ± 11.07
TTE (s)	754.23 ± 81.41	780.00 ± 88.08	760.15 ± 120.01	761.33 ± 121.99
BMI	27.67 ± 6.27	27.09 ± 6.48	26.07 ± 7.52	26.62 ± 8.08
Body Fat (%)	28.58 ± 9.04	28.93 ± 9.25	24.40 ± 9.01	25.01 ± 8.98
Trails A (s)	21.77 ± 9.50	18.00 ± 4.65#	23.46 ± 8.35	18.77 ± 4.59#
Trails B (s)	47.62 ± 17.36	33.85 ± 12.56#	51.23 ± 17.94	38.77 ± 13.30#
Switch cost (s)	25.85± 17.35	15.85 ± 9.49#	26.92 ± 18.99	20.00 ± 12.56#

There was no correlation between baseline VO_2 max and the initial skill assessment (r = 0.0005). There was no correlation between baseline VO_2 max and scores at C_1 (r = 0.001). There was a strong direct correlation between the initial skill assessment and scores at C_1 (r = 0.912).

a)



b)



c)

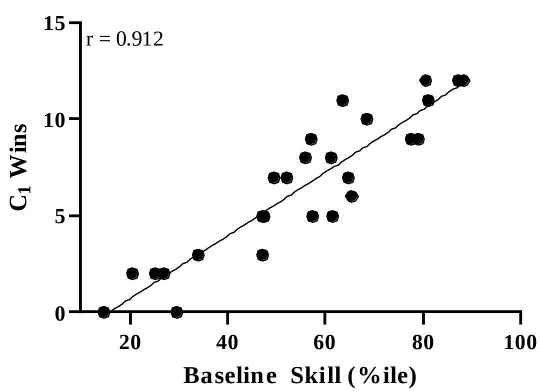


Figure V-4. Correlation between VO_2 max, C_1 Wins, and Baseline skill

Note: C_1 wins indicate the total wins accumulated at the first competition. Baseline skill (expressed as a percentile) was determined by average results in double elimination brackets for eight weeks prior to the study.

In the acute exercise logistic regression model there was a significant effect of group ($p = 0.00672$, log-odds ratio = 0.7178, exp = 2.049918). In the chronic endurance regression model, there was no significant effect of group (log-odds ratio = 0.3711, exp = 1.45p = 0.130). In the combination logistic regression model there was a significant effect of group ($p < 0.001$, log-odds ratio =1.5476, exp = 4.695984).

Table V-5. Logistic regression output for all models

Note: *Exp*, Exponentiated; *CI*, Confidence intervals C_1-C_4 indicate eSport performance scores (expressed as proportion of accumulated wins to total sets played) at competitions 1-4; respectively. The log-odds outputs are exponentiated for interpretation. * Indicates significance ($p \leq 0.01$).

Exp, Exponentiated; *CI*, Confidence intervals

Acute (C_1 | C_2)	Log-Odds	Exp(log-odds)	P value	2.5% CI	97.5% CI
Intercept	-0.399	0.671	0.030*	-0.749	-0.028
C_1 Win	4.861	129.269	2e-16*	3.778	6.053
Group	0.717	2.050	0.007*	0.205	1.246
Chronic (C_1 | C_3)	Log-Odds	Exp(log-odds)	P value	2.5% CI	97.5% CI
Intercept	-0.213	0.808	0.219	-0.544	0.136
C_1 Win	3.762	43.040	6.4e-14*	2.812	4.784
Group	0.371	1.449	0.130	-0.107	0.857
Combined (C_1 | C_4)	Log-Odds	Exp(log-odds)	P value	2.5% CI	97.5% CI
Intercept	-0.803	0.448	1.9e-05*	-1.166	-0.430
C_1 Win	4.298	73.567	6.1e-14*	3.22	5.47
Group	1.547	4.69	1.85e-08*	1.021	2.102

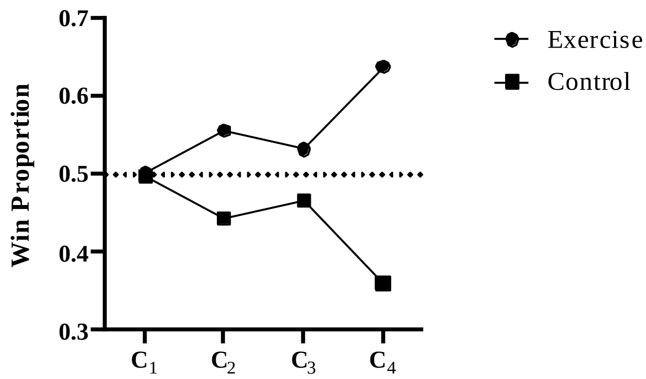


Figure V-5. eSport performance across all timepoints.

Note: C_1-C_4 refer to competitions 1-4; respectively. At each competition, eSport performance was recorded as win proportion (total wins accumulated divided by the total number of sets played).

Discussion

The purpose of this study was to determine the effects of acute exercise and chronic endurance training on eSport performance. Performance was measured by a proportional win rate in a semi-round robin SSBU Competition. Statistical models were then constructed to assess the effect of each intervention. Effects of acute exercise were observed by a model comparing results at C_1 and C_2. Chronic effects were observed at C_1 and C_3, and the combined acute exercise and endurance training intervention (overall effect of the study) was observed comparing C_1 to C_4 (Figure 1). At timepoint C_4, the Exercise group participated in the competition after completion of an acute HIIT bout similar to C_2. However, this took place after the eight-week chronic endurance training period. Thus, the combined model observed the effect of the acute HIIT bout on eSport performance after eight weeks of exposure to HIIT, or a "combination" effect of an acute HIIT protocol and chronic HIIT. The logistic regression analysis of each model provided the odds that a participant would win at a specific timepoint (C_2, C_3 or C_4), assuming they did not win a single set at timepoint C_1. The logistic regression models were centered around the mean win proportions at C_1 so that the exponentiated intercept log-odds could be interpreted to mean "the percent chance that a member of the Exercise group would win, assuming their win % at C_1 was 50%). Pre-and post-testing functioned as an implementation check to assess whether eSport performance changes could be explained by changes in cardiovascular physiology or cognition.

Our primary finding is that an acute HIIT bout immediately prior to competition increases a competitor's chance to win. Exponentiated log-odds of a non-centered intercept indicate that Exercise group participants who won 0 sets at C_1 had a 6% chance of winning at future timepoints. After acute exercise, a competitor would increase their chance to win to 12%. Thus, the acute model results suggest that participants who did not win a single set at C_1 would double their chance of winning after acute exercise. While the acute exercise seems to double a participant's chance of winning, a more intriguing finding is present when observing the results of the combination exercise model.

The combined model includes both acute and chronic training. The exponentiated log-odds (4.7) indicate that a participant who did not win a single set at C_1 would increase their chance of winning by 4.7 times (28.3% chance of winning) if they were exposed to the same acute exercise bout prior to C_2 and following eight weeks of chronic endurance training prior to C_4. While acute exercise alone doubles a participant's chance of winning, that effect is compounded if the participant completed an eight-week HIIT program prior to the exercise bout.

The effects of acute exercise on eSport performance are clearly present. Findings from this study present preliminary evidence that acute exercise increases chances of winning in SSBU competitors. However, due to the size of the confidence intervals, larger studies are needed to accurately estimate the magnitude of this effect. In the present study, the researchers did not assess any cognitive function changes after acute exercise. Although there was an increase in performance following acute exercise in both the acute and combination models, we are unable attribute this to the effect of exercise on cognitive function with our current data. Furthermore, the lack of group effect for any pre- to post-test variable makes it difficult to elucidate the mechanism by which chronic and acute endurance exercise interact. According to our data, we cannot attribute any group differences in performance increase in the combination model to an increase in VO_2 max consumption or cognitive performance.

The effect of exercise in the chronic model did not reach statistical significance ($p = 0.13$). Although, the change in performance due to chronic exercise was roughly 40% in the expected direction. It is reasonable to assume, based on our data and study design, that the effect of chronic exercise is smaller than can be detected with this sample size. However, our data suggest that if a chronic training effect was detected it would not be explained by changes in the physiological or cognitive variables assessed in this study.

The Exercise group did not experience a significant increase in VO_2 max despite participation in an eight-week endurance training program. The Exercise group had an average pre- to post-test increase in TTE of 25 seconds, but this increase was not statistically significant. We explore the reasoning for this lack of increase in the limitations section of the manuscript. Regardless, results of baseline testing indicate there may not be a relationship between VO_2 max and eSport performance ($r = 0.0005$), so this may not be a relationship worth investigating in future studies.

Trails Task switch cost scores assessing visuomotor performance via task switching improved over time in both groups ($p = 0.048$). The lack of group differences for Trails Task times contradicts results from previous studies revealing scores of cognitive function increased after an endurance training program [37, 40, 41]. Furthermore, baseline Trails Task means in both groups were comparable to means of normative Trails data in high-school educated participants ages 18-24 (Trails A: 22.93 ± 6.87; Trails B: 48.97 ± 12.96) [199]. This contradicts findings from previous literature that action video game players tend to score higher on tests of cognitive function [29-31]. It should be noted that, regardless of exercise, action video game interventions have been used to improve scores on tests of cognitive function [24-27]. It is possible that the four competitions, additional regular-season competitions outside of the study, and time spent practicing during the eight-week chronic portion served as a video game intervention that improved the Trails scores in both groups. However, we did not collect average playtime for eight weeks prior to the study as a baseline for playtime, so we cannot comment on this interaction. It is also possible that the participants remembered the pattern (learning effect) from the pre-testing Trails Task resulting in faster times. Perhaps there is not a relationship between the effect of exercise on Trails scores and eSport performance; it would be worthwhile for future researchers to measure alternative cognitive variables in this population.

We assessed VO_2 max means before C_1 (Exercise; 40.93 ± 7.18: Control; 41.62 ± 9.17) to ensure our groups were comparable at baseline. There were no VO_2 max differences between groups at baseline ($p = 0.81$). Both groups were also comparable to normative data for men and women of a similar age range (men: 44.2 ml · kg^{-1} · min^{-1}; women: 37.8 ml · kg^{-1} · min^{-1}) [205].

There was no relationship between fitness level and eSport performance in our sample. The lack of a correlation between VO_2 max and average placement at tournaments eight weeks prior to the study ($r = 0.0005$) contradicts our hypothesis that there would be a positive linear relationship between fitness level and skill. This is compounded by results at C_1, where we found no relationship between VO_2 max and eSport performance scores at C_1 ($r = 0.001$). There was a strong direct correlation between average placements at tournaments eight weeks prior to the study and scores at C_1 (r = 0.912). Even though our round robin competition methodology did not exactly emulate the double elimination competition style in tournaments outside of the study, results from both were very strongly correlated. This not only functions as validation that pairs were skill-matched correctly at baseline, but it also provides the groundwork for future eSport researchers who plan to observe results of different tournament styles utilized in eSport competitions.

Limitations to the study include participant motivation, logistic issues with the eSport collections (C_1-C_4), and outside factors that influenced post-testing. SSBU features 81 playable characters that function as the competitor's avatar. Players will often play a "main," or a character they typically utilize in a competitive setting. Players often have "secondaries," or another character they play less often which likely impacted their success. At timepoints C_2 and C_3, five (three Control, two Exercise) of the participants played secondaries, noting that they wanted to take the opportunity to practice with a different character. It is likely that playing a secondary would negatively affect eSport performance. Answers to participant follow ups indicate that since competitions did not contribute to state rankings, some participants were not incentivized to compete to win despite the opportunity for a large payout. Future studies in this area may consider locking participants into a character throughout the duration of the study. Researchers may also consider alternative incentives to encourage maximal effort during competition, since for at least five of the 26 participants the opportunity for financial gain was not the primary motivator for maximal effort.

Due to the design of the competitions, there may have been a contribution of the winner-loser effect studied in human competition. This effect postulates that winning a match increases the likelihood that a human competitor in sport will win their next match [206]. Additionally, there is evidence that a "home court advantage" is required for a true winner loser effect to take place [207]. If a participant won their first set, it is possible that this had a positive effect on their ability to play in the next 12 sets.

The largest limitations of the present study were the obstacles faced during post-testing. Of the 13 participants in the Exercise group, there is an argument for excluding VO_2 max post-test data for seven. Four of the post-tests had to be delayed to up to three weeks after the conclusion of the chronic exercise period due to injury, sickness, infection, and intoxicating substance use. Additionally, three participants did not give maximal effort during the VO_2 max test, and all three opted not to redo the test. Four of these seven participants experienced decreases in VO_2 max from baseline despite participation in an eight-week HIIT protocol. These decreases can be explained by not reaching maximal effort during VO_2 max testing, and by a detraining effect that has been recorded to manifest within 14 days of stopping an exercise program [208, 209]. Future efforts to assess the chronic effect of endurance training on eSport performance could use a slightly altered study design to avoid an effect of detraining, in which post testing occurs before timepoints C_3 or C_4. However, this runs a logistic risk of losing the ability to observe the full effect of exercise on eSport performance, with an accurate VO_2 max measurement as the tradeoff.

Conclusion

This study was the first to observe the direct effects of acute and chronic exercise on eSport performance scores. Results from the study indicate a positive effect of acute exercise on bracket performance in SSBU competitors. The results from this study also indicate that there is a positive combined effect of acute exercise and chronic endurance training on bracket performance in SSBU competitors.

Future work should include larger sample sizes and alterations to the study design in which post testing is completed before timepoints C_3/C_4 and cognitive function is assessed after acute exercise.

Chapter VI

Research Summary, Additional Findings, and Future Work in eSport Performance

Purpose

This chapter will provide additional findings not yet submitted for publication, obstacles faced by the research team, and lessons learned. These factors combined will help set the stage for a future line of eSport performance research.

Exploratory Data

The purpose of my dissertation was to be the first study to explore the relationship between exercise and eSports using an experimental design. As such, we only reported on the effects that our exercise interventions had on increasing the probability of winning in eSport competitions. We considered our results from exercise and eSport interventions to be our confirmatory data. We also collected several other variables that might impact our findings and inform future work. These other data were deemed exploratory.

We utilized a linear regression model to determine if any of these additional data had a significant impact on change in eSport performance. These data were used to construct models which functioned as predictors for changes in eSport performance across all timepoints (C_1-C_4). The models and their included data are listed in Table 1.

Table VI-1. Additional data collected immediately post-collection and during the eight-week chronic intervention period

Note: *VO_2*, oxygen consumption; *bmi*, body mass index; *THC*, Tetrahydrocannabinol (marijuana); *SSBU*, Super Smash Brothers Ultimate

Model	Data
Physiological	Pre-post VO_2 max, bmi, and %bodyfat changes
Cognitive	Pre-post manual and digital Trails Task changes
Skill	Changes in average placement in double elimination brackets outside of the study, set win % and game win % between baseline testing and the end of the 8-week endurance intervention period.
Exercise perception	Changes scores between all timepoints for participant perceptions on the effect of both fitness and acute exercise on eSport performance (5-point Likert Scale)
Substance use	Change in caffeine, THC, medication (prescribed or non-prescribed), or any other ergogenic aid use between all timepoints (24-hour recall)
Acute competition prep	Changes in sleep, practice, and video review recall questionnaire between all timepoints. (24-hour recall)
Chronic competition prep	Total SSBU practice time, video review, and competitions entered during the 8-week endurance intervention period (8-Week Log)
Factors during gameplay	Nerves, fatigue, and the effect of an opponent becoming visibly upset during competition (5-Point Likert Scale).
Chronic exercise	Total endurance training and resistance training during the 8-week endurance intervention period. (8-Week Log)

We constructed our linear regression models in a similar fashion to the binary logistic regression models used during statistical analyses in Chapters 4 and 5. We constructed a model for the acute arm of the study using eSport performance change scores between C_1 and C_2, a chronic model using eSport performance change scores between C_1 and C_3, and a combination exercise model using eSport performance change scores between C_1 and C_4. We constructed one additional model to assess the effect of any pre-test measurement on scores at C_1 independent of group. Appropriate models listed in Table 1 were used as predictors for eSport performance change scores at each timepoint. Means and Standard Deviations for all data per group are provided in Table 2.

Table VI-2. Additional Values. Individual Competition values collected at each timepoint. 8-week Chronic Period values were collected via participant logs during the chronic arm of the study. All values were recorded in minutes.

	Exercise (*n=13*)	**Control *(n=13)***
Individual Competition Values		
C_1 Sleep	452.30 ± 109.18	425.07 ± 106.37
C_2 Sleep	410.77 ± 140.38	392.31 ± 143.59
C_3 Sleep	454.61 ± 107.36	436.36 ± 201.41
C_4 Sleep	431.54 ± 151.26	417.69 ± 180.60
C_1 Warm-up	110.77 ± 144.56	186.92 ± 221.19
C_2 Warm-up	76.15 ± 105.79	83.07 ± 118.21
C_3 Warm-up	101.53 ± 141.53	41.45 ± 87.99
C_4 Warm-up	53.07 ± 86.73	49.84 ± 72.18
C_1 Video Review	18.46 ± 66.56	73.85 ± 117.87
C_2 Video Review	4.61 ± 16.64	13.06 ± 33.51
C_3 Video Review	2.30 ± 8.32	5.45 ± 18.09
C_4 Video Review	23.07 ± 67.25	0 ± 0
8-week Chronic Period Values		
Cardio	967.57 ± 612.62	925.61 ± 1352.25
Resistance Training	63.07 ± 149.91	308.84 ± 813.62
Practice Time	3461.08 ± 1602.37	2830.92 ± 1900.56
Competitive Time	1786.15± 1602.37	1211.36 ± 1490.30
Number of Competitions	7.07 ± 3.2	4.53 ± 5.15
Video Review	167.46 ± 343.25	698.38 ± 1537.27

Exploratory Data Results

Results from the C_1 model suggest that the only predictor of score at C_1 was average placement of the participant at double elimination events for the eight weeks preceding data collection ($p = 0.007$). There were no significant effects of the physical, substance use, perception, or acute competition preparation models ($p \geq 0.05$).

Results from the model observing changes from C_1-C_2 suggest that there were no other factors that affected changes in score from C_1-C_2 other than the exercise intervention. There was no effect of exercise perception, acute tournament prep, or substance use ($p \geq 0.05$).

Results from model observing changes from C_1-C_3 suggest that the predictors of eSport performance change scores include pre-post changes in Digital Trails A side ($p = 0.03$) and switch cost scores ($p = 0.04$) and change in tetrahydrocannabinol (THC) use ($p = 0.03$). There were no significant effects of the physical, factors during gameplay, skill, perception, acute prep, chronic prep, or chronic exercise models ($p \geq 0.05$).

Results from the model observing changes from C_1-C_4 suggest that the predictors of eSport performance change scores include pre-post changes in the Digital Trails Task A ($p = 0.03$) and B ($p = 0.03$) sides, pre-post changes in the manual Trails Task B Side ($p = 0.003$), change in THC use ($p = 0.04$), and a change in the effect of an opponent becoming visibly upset ($p = 9.45e^{-5}$).

Exploratory Data Discussion

Round Robin vs Double Elimination Tournaments

The only factor that affected a participant's ability to perform at C_1 was their average placement in double elimination events for the eight weeks prior to the study. This is unsurprising, as we would expect a competitor who usually places well in tournaments outside of the study to also do well during the study at C_1 (prior to interventions). What is of note is the strength of the correlation between C_1 performance scores and average placement in tournaments for eight weeks prior to the study ($r = 0.933$).

The semi-round robin competition style used at C_1 does not emulate the double elimination style of SSBU tournaments used during the regular season competitions prior to the study. In the double elimination style, each competitor receives a "seed" based on their previous performance. That seed determines their tournament path to the finals. A player with a low seed faces a tough opponent in the first round. Typically, the lower seeded player will lose and will be immediately sent to the loser's side of the bracket. A player sent to loser's side early will have to win more sets to win the tournament. This competition style leads to every competitor playing a different number of sets, all with varying numbers of wins. In addition, there are often "upsets" in the winner's side of the bracket where a highly seeded player will lose early for any number of reasons, and then will win the tournament from the loser's side. For all these reasons, we deemed the double elimination style of tournament unfit to be used in a study with an experimental design, and instead opted for a semi-round robin style tournament. Interestingly, the double elimination style backet has recently come under investigation as an inappropriate way to host tournaments for the same reasons we did not use it during the study. Tournament organizers have suggested using round robin style tournaments instead. The idea is that round robin tournaments will give a more accurate description of a player's skill, because they play every other participant in the tournament at least once. The tradeoff is time. For example, a 32-participant double elimination style bracket with 16 setups takes less than two hours to complete. A 32 participant round robin style bracket with 16 setups lasts roughly six hours.

Results from our studies suggest a strong correlation between a participant's average results from double elimination brackets and their wins accumulated during the semi-round robin ($r = 0.933$) suggesting no results-centered benefit to running a round robin style competition. It is worthwhile for tournament organizers to consider that double elimination tournaments and round robin tournaments may yield similar results. If there is a benefit to a round robin competition, it may not outweigh the detriment of additional time to complete the tournament.

Trails Task Data

In addition to the manual (pen and paper) Trails Task, we collected Trails Task data (A and B side) in all participants using a digital version of the test. In the digital version, participants utilized a personal controller to complete the task. Participants manipulated the left joystick on the controller instead of drawing a line from item-to-item with a writing utensil.

A predictor of change in eSport performance independent of exercise were the changes in the digital Trails Task A side ($p = 0.03$) B side ($p = 0.03$) side, switch cost ($p = 0.04$), and manual Trails Task B Side ($p = 0.003$). In the digital test, the Trails appeared on a computer screen, and the test was completed utilizing the left joystick on a GameCube (Nintendo, Kyoto, Japan) or Nintendo Switch (Nintendo, Kyoto, Japan) pro controller. This is interesting, as digital and manual Trails Task scores improved in many of the control group participants, including those who did not participate in regular exercise during the chronic intervention period.

Changes in digital Trails Task scores also did not reflect changes in the manual Trails Task. These patterns, combined with the finding in Chapter 4 that participants who scored worse on the manual Trails Trask performed better at C_1, suggest that there may be a better way to assess cognitive function in E-athletes than traditional pen and paper tests. These data will be used in a manuscript (in progress) to validate the use of a digital Trails Task when measuring visuomotor performance and task switching in E-athletes.

Substance Use Data

After data collection at each timepoint, participants completed a post-competition survey. Part of this survey was a 24-hour sleep, gameplay, practice time, and substance use recall. While there were no significant effects of gameplay, sleep, or practice time on performance ($p \geq 0.05$), there was a significant effect of change in THC use from C_1 to C_3 ($r = 0.38$) and THC use from C_1 to C_4 ($p = 0.04$). This suggests that a competitor who utilized THC prior to C_1 would perform worse if they did not use THC prior to C_3/C_4. Future studies should investigate the effects of THC on eSport performance. There were no significant effects of change in consumption of caffeine, alcohol, prescribed medication, intoxicating substances other than THC, or nicotine ($p \geq 0.05$).

Tilt Data

In addition to the 24-hour recall, participants also answered survey questions regarding their perception of exercise, fitness, nervousness, and additional factors affecting their gameplay. There were no significant effects of change in any factor ($p \geq 0.05$) other than the effect of an opponent becoming visibly upset ($p = 9.45e^{-5}$). Becoming visibly upset during competition in eSport is colloquially referred to as “tilt.” The concept of tilt has not made its way into peer reviewed research but is closely related to the winner-loser effect detailed in Chapter 5. I interviewed professional eSport coach Ryan Kirchbaum about the concept of tilt (R.Kirchbaum, personal communication via Discord ® call, May 10, 2022). He comments “Tilt is the mental state where a player abandons any preformed gameplans or strategies due to a certain level of frustration. Tilting ends up in a feedback loop where they begin to lose even more because they’re tilted, and because they lose more, they get more tilted.” Mr. Kirchbaum would go on to comment about how players tend to be unnecessarily aggressive when they’re tilted, often resulting in a loss. Interestingly, there was no relationship between eSport performance changes and tilt in the current study ($p = 0.81$). However, there was an effect of a participant noticing that their opponent was tilted. The participants were asked this question:

“What is the effect of an opponent becoming visibly upset on your gameplay?”

Very Negative   Negative   No Effect   Positive   Very Positive

The results from our exploratory data suggest that the players who improved their eSport performance scores from C_1 to C_4 responded differently to this question at each timepoint. Participants who experienced the largest increases in performance answered “Very Negative” at C_1 and answered “Very Positive” at C_4. Conversely, players who experienced decrements in eSport performance scores answered “Very Positive at C_1 and “Very Negative” at C_4. It appears that one of the primary factors influencing change in performance was the effect that an opponent becoming upset had on their gameplay. Those who improved went from letting an opponent’s tilted state influence their gameplay negatively, to using their opponents tilted state as a tool to win. It should be noted that these changes occurred independent of group, and therefore independent of any exercise intervention. From these data alone, it is worthwhile for a future researcher to examine the effect of an opponent's tilt on eSport performance in SSBU competitors.

eSport Population Obstacles

Sample Skill

In any research study, it is assumed that the sample population studied is an accurate representation of the population. One potential criticism of this study is that the sample studied (SSBU competitors in Auburn and Montgomery Alabama) does not accurately reflect the population (eSport competitors in North America). There may be a skill issue.

SSBU in North America is divided into large regions. Each of those regions has smaller subregions. Large regions within North America include the Midwest, Southern California, Northern California, Tri-State, Northeast, MDVA (Maryland/Virginia/DC), Pacific Northwest, Texas, Georgia, Florida, and the remaining Southeast. The remaining Southeast is widely considered to be the least-talented subregion, with only one competitor from Alabama, Louisiana, Arkansas, Tennessee, or Mississippi making it onto the Top 50 Power Ranking (PR) for SSBU in the game's lifespan. That player has since been banned and is no longer active.

Alabama as a region has seen some recent success, but traditionally the Top 10 ranked players in Alabama do not perform to expectations when traveling out of region. Two examples are the recent major events "Southern Ohio Smash 7" and "Code Crimson." At Southern Ohio Smash 7, despite half of Alabama's Top 10 attending, there were no Alabama representatives in Top 16 of the bracket. At "Code Crimson" there were only two Alabama representatives in Top 16 of the bracket despite 93% of entrants being from Alabama.

Within the state of Alabama, there are eight subregions including Birmingham, Tuscaloosa, Florence, Huntsville, Wiregrass (Dothan), Mobile, Northeastern Alabama Smash League (NEASL), and Auburn. Alabama tournament organizers typically rank Auburn as the lowest or second lowest ranking subregion only ahead of NEASL which has recently dissolved. For example, there are no representatives from the Auburn Subregion on the current Top 15 Alabama PR.

Of the 30 participants who pre-tested for the study, 24 were from the Auburn subregion, and six were from the Birmingham subregion. The top scorers at C_1-C_4 were all Birmingham competitors with only one exception. There is an argument that the sample studied was on the lower end of skill for SSBU on a national scale. Future researchers should repeat this study within a different sample of the same population to observe the effects of exercise on higher-skilled regions in SSBU.

Participant Attrition and Scheduling Delays

During recruitment, we garnered interest from 54 potential participants. After individual initial meetings with all 54 participants about the details of the study, 38 of those 54 scheduled pre-tests, and 30 came in for pre-testing. Of the 30 participants who pre-tested, two dropped before group assignment, and one exercise group participant dropped out of the study during the chronic endurance intervention period. We had to then exclude data from their control group matched pair. All participants were scheduled for post-testing within one week of C_4. Fourteen of those participants rescheduled up to three weeks after conclusion of C_4, leading to a detraining effect. Table 2 lists the number who either dropped out of the study or caused scheduling delays since recruitment.

Table VI-3. Description of participant attrition and causes of scheduling delays. Attrition includes loss of interest from recruitment to pre-testing, as well as participants who dropped out of the study during collection.

Cause of Dropout or Delay in Scheduling	Number of conflicts
Mask requirements during all testing	10
Conflict with church (Easter or otherwise)	7
Conflict with bible study	1
Conflict with fraternity party	2
COVID-19	4
Banned for hate speech	2
Showed up to testing under the influence of drugs or alcohol	4
Lost contact with participant	8

Sample Obstacles

The primary obstacle for data collection due to group assignment was timing. The competitions required every participant to be present. Furthermore, at C_2 and C_4 the Exercise group had to be present for one hour longer than the Control group so they could perform the exercise protocol. At both C_2 and C_4, there were four Exercise group participants who arrived 2.5 hours after the scheduled time. This delayed collection by three hours. Thus, C_2 and C_4 did not start at the same time as C_1 and C_3. Additionally, researchers observed that the participants who arrived at the scheduled time were visibly upset with the late participants. The research team observed that this caused a change in playstyle where the participants who were upset stopped playing to win, and instead started playing to annoy the participants who were late. While this likely affected results of the competition, it also provides grounds for a study observing the effects of interpersonal relationships with opponents on eSport performance.

During the chronic endurance intervention period, participants scheduled one-hour blocks for their exercise training. The four Exercise group participants who arrived chronically late to collections also arrived late to their exercise trainings. This caused delays in scheduling and overlapping exercise schedules with other participants. Furthermore, two of those same participants attempted to train multiple times under the influence of intoxicating substances. Each time this happened, the training had to be rescheduled. These same participants arrived at post-testing under the influence of intoxicating substances, and so their VO_2 max tests had to be rescheduled up to two weeks. This led to a potential detraining effect and a decrease in quality of the collected VO_2 max data for the exercise group. While many of the listed problems we encountered could be encountered regardless of the population studied, there were a few changes that could be made to the study design to help combat these obstacles in future research.

Future Research

Crossover Design

The original study design called for an ANCOVA analysis to observe the changes in mean eSport performance scores between groups across all four timepoints. At the end of the day, it was possible for the means to be compared this way, but it wasn’t necessarily appropriate. Since each member of the control group competed against each member of the exercise group, there was one winner and one loser during every interaction. In this sense, for the average of the exercise group to increase, the average of the control group had to decrease. This phenomenon is evident when observing Figure 1 that displays the mean changes over time for each group.

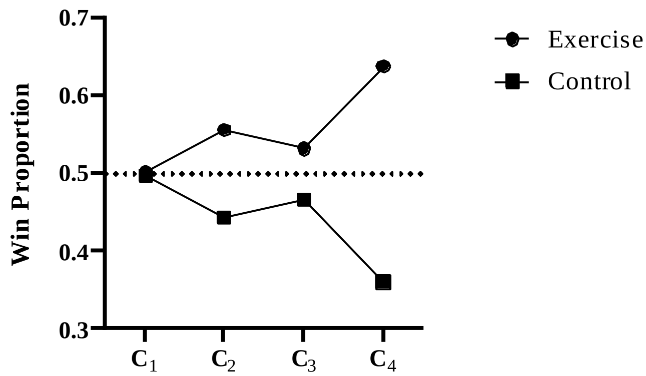


Figure VI-1. eSport performance across all timepoints. C_1-C_4 refer to competitions 1-4; respectively. At each competition, eSport performance was recorded as win proportion (total wins accumulated divided by the total number of sets played).

Performing an ANCOVA on these mean data would run the risk of detecting a difference between groups due to family-wise error. For this reason, we elected to use a binary logistic regression model with an α priori alpha level of 0.01 and clustered variance to utilize group as a predictor for improving odds of winning, instead of simply comparing means between groups at each timepoint. While this did not eliminate the violation of the assumption of independence for statistical analysis, the use of logistic regression could at least frame the results in a way that would be valuable for future researchers.

If a future researcher wanted to compare means at each timepoint, they would have two options: 1) the addition of a third group to act as a true control; or 2) implementation of a crossover design. Both options were considered during the first committee meeting before data collection began. It was the decision of the primary researcher and the committee to use our current study design due to the design's simplicity and the novelty of the collected data. Now that I have completed an exercise and eSport study, I would be inclined to utilize the cross-over design in the future. There is value to a design using an additional group, but I would advise against it for researchers specifically wanting to study the SSBU population. In SSBU power rankings, head-to-head results between players are often valued more than average results at tournaments. Thus, a design observing direct results of competition between two players is more translatable to the eSport than observing the average of two different players against a third player.

Post-Testing Scheduling

As discussed in Chapter 5 and the beginning of Chapter 6, the time between C_4 and post-testing posed a large obstacle for statistical analysis. Namely, the up to four-week delay between the end of the exercise period and the final VO_2 max test for many participants allowed time for a detraining effect to set in. There is an argument that most of the VO_2 max data did not accurately reflect changes in VO_2 max of the participants. This resulted in no change from pre- to post-test in the exercise group, so any changes in eSport performance could not be attributed mechanistically to a change in maximal oxygen consumption. Originally, post-testing for all participants was scheduled one week after C_4. This meant that all post-testing took place within two weeks of the end of the exercise period, which would not be enough time for a detraining effect to take place. Unfortunately, many of the participants had to reschedule their post testing far beyond this two-week timeframe. This problem could be solved with a simple change in study design. Instead of post-testing after C_3 and C_4, a future design could post-test before C_3 or C_4. Figure 2 below shows the change to the design.

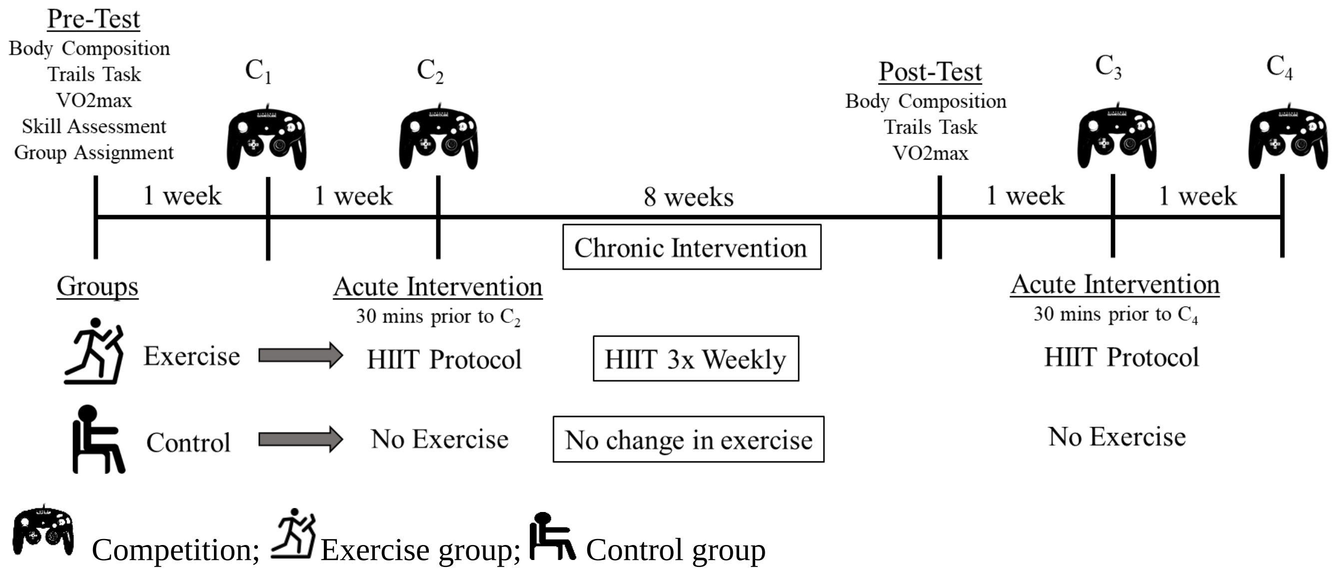


Figure VI-2. This is an alternative methodological design to our study. In this design, post-testing is completed before competitions C_3 and C_4.

Re-Assessment of Cognitive Variables

The results from our study suggest a significant effect of acute exercise. Unfortunately, we only collected cognitive variables during pre-testing and post-testing, so we could not attribute the acute increase in eSport performance to the effect of a HIIT bout on cognitive function. Any study in the future should consider testing all cognitive data after an acute HIIT bout for all participants.

Establish Baseline Physical Activity and Gaming

It would have been valuable to establish a baseline for physical activity and gameplay of all participants. This would serve two purposes. Instead of simply asking the control group participants to make no changes to their exercise habits, we could establish an exercise regimen for the control group participants that exactly mimics their regular exercise habits for the eight weeks preceding the study. This would ensure that they neither increased nor decreased the volume of exercise they completed during the training study. This would have been particularly helpful, as one of the control group participants increased their VO_2 Max by 12 ml $\cdot kg^{-1} \cdot min^{-1}$ (pre: 52.1 ml $\cdot kg^{-1} \cdot min^{-1}$; post 64 ml $\cdot kg^{-1} \cdot min^{-1}$). During follow-up and observation of the participant's eight-week exercise log, we concluded that the participants added six hours of extra cardio per week to their regular exercise regimen, as they thought it would improve their results outside of the study. Two other control group participants admitted to making changes to their exercise habits to improve their cardiovascular fitness, but interestingly their VO_2 maxes decreased from pre-testing. It should be noted that control group participants were specifically instructed to make no changes to their exercise habits at multiple timepoints including 1) the consenting process; 2) after timepoint C_2; 3) a Discord ® message sent to each participant after group assignment; and 3) every two weeks during the study both through an individual message and during a Discord® call check in.

The second value of the baseline measurements would be detecting changes in total gameplay time during the intervention. One result from the exploratory data was that improvement in digital Trails Task changes was a significant predictor of improvement in eSport performance. We originally hypothesized that chronic endurance training would improve cognitive function, and this would in turn cause an improvement in Trails Task scores in the exercise group. Instead, many participants improved their scores for both the manual and digital tasks regardless of group. Previous literature indicates an effect of action video games on improving tests on scores of cognitive function. It is possible that the participants increased the amount of time they spent practicing in preparation for the study, and this served as an action video game intervention which acutely improved their cognitive function between pre-testing and posting. However, since we did not have any baselines measurements for comparison, we either can't comment on this mechanism, or there is a learning effect on Trails Task scores.

Conclusion

This dissertation was the first study to observe the effects of acute and chronic exercise on eSport performance. As such, there were many unforeseen obstacles. However, with experience gained from completion of this project we have gained insight into potential changes in study design for follow up studies. Furthermore, exploratory work from this study has paved the way for numerous follow-up studies in eSport performance.

References

1. Toth, A.J., et al., *Converging Evidence Supporting the Cognitive Link between Exercise and Esport Performance: A Dual Systematic Review.* Brain sciences, 2020. **10**(11): p. 859.
2. Anderson, C.A., *An update on the effects of playing violent video games.* Journal of adolescence, 2004. **27**(1): p. 113-122.
3. Kirsh, S.J., *The effects of violent video games on adolescents: The overlooked influence of development.* Aggression and violent behavior, 2003. **8**(4): p. 377-389.
4. Sherry, J.L., *The effects of violent video games on aggression: A meta-analysis.* Human communication research, 2001. **27**(3): p. 409-431.
5. Weaver III, J.B., et al., *Health-risk correlates of video-game playing among adults.* American journal of preventive medicine, 2009. **37**(4): p. 299-305.
6. Altintas, E., et al., *Sleep quality and video game playing: Effect of intensity of video game playing and mental health.* Psychiatry research, 2019. **273**: p. 487-492.
7. Naser, S.S.A. and M.H. Al-Bayed, *Detecting Health Problems Related to Addiction of Video Game Playing Using an Expert System.* 2016.
8. Oh, Y. and S. Yang, *Defining exergames & exergaming.* Proceedings of meaningful play, 2010. **2010**: p. 21-23.
9. Brox, E., et al. *Exergames for elderly: Social exergames to persuade seniors to increase physical activity*. in *2011 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops*. 2011. Ieee.
10. Best, J.R., *Exergaming in youth.* Zeitschrift für Psychologie, 2015.
11. Oberhauser, M., et al., *What's Real About Virtual Reality Flight Simulation?* Aviation Psychology and Applied Human Factors, 2018.
12. McCloy, R. and R. Stone, *Virtual reality in surgery.* Bmj, 2001. **323**(7318): p. 912-915.
13. Neumann, D.L., et al., *A systematic review of the application of interactive virtual reality to sport.* Virtual Reality, 2018. **22**(3): p. 183-198.
14. Franceschini, S., et al., *Action video games make dyslexic children read better.* Current Biology, 2013. **23**(6): p. 462-466.
15. Franceschini, S., et al., *Action video games improve reading abilities and visual-to-auditory attentional shifting in English-speaking children with dyslexia.* Scientific Reports, 2017. **7**(1): p. 1-12.
16. Stewart, S., *Video game industry silently taking over entertainment world.* Ejinsight, Tech, Media & Telecom. Acedido a, 2019. **19**: p. 11-19.
17. Heaven, D., *Esports: Pro video gaming explodes with big prize pots.* New Scientist, 2014.
18. Reitman, J.G., et al., *Esports research: A literature review.* Games and Culture, 2020. **15**(1): p. 32-50.
19. Bediou, B., et al., *Meta-analysis of action video game impact on perceptual, attentional, and cognitive skills.* Psychological bulletin, 2018. **144**(1): p. 77.
20. Hilvoorde, I.v. and N. Pot, *Embodiment and fundamental motor skills in eSports.* Sport, Ethics and Philosophy, 2016. **10**(1): p. 14-27.
21. Latham, A.J., et al., *Earlier visual N1 latencies in expert video-game players: a temporal basis of enhanced visuospatial performance?* Plos one, 2013. **8**(9): p. e75231.
22. Parshakov, P. and M. Zavertiaeva, *Determinants of performance in eSports: A country-level analysis.* International Journal of Sport Finance, 2018. **13**(1): p. 34-51.
23. Pluss, M.A., et al., *Perceptual-motor abilities underlying expertise in esports.* Journal of Expertise, 2020. **3**(2): p. 133-143.
24. Hutchinson, C.V., et al., *Action video game training reduces the Simon Effect.* Psychonomic bulletin & review, 2016. **23**(2): p. 587-592.

25. Oei, A.C. and M.D. Patterson, *Enhancing perceptual and attentional skills requires common demands between the action video games and transfer tasks.* Frontiers in psychology, 2015. **6**: p. 113.
26. Sanchez, C.A., *Enhancing visuospatial performance through video game training to increase learning in visuospatial science domains.* Psychonomic Bulletin & Review, 2012. **19**(1): p. 58-65.
27. Wu, S. and I. Spence, *Playing shooter and driving videogames improves top-down guidance in visual search.* Attention, Perception, & Psychophysics, 2013. **75**(4): p. 673-686.
28. Wong, N.H. and D.H. Chang, *Attentional advantages in video-game experts are not related to perceptual tendencies.* Scientific reports, 2018. **8**(1): p. 1-9.
29. West, G.L., et al., *Habitual action video game playing is associated with caudate nucleus-dependent navigational strategies.* Proceedings of the Royal Society B: Biological Sciences, 2015. **282**(1808): p. 20142952.
30. Wang, P., et al., *Age-related cognitive effects of videogame playing across the adult life span.* Games for health journal, 2017. **6**(4): p. 237-248.
31. Kowal, M., et al., *Different cognitive abilities displayed by action video gamers and non-gamers.* Computers in Human Behavior, 2018. **88**: p. 255-262.
32. Gebel, C., M. Gurt, and U. Wagner, *Kompetenzförderliche Potenziale populärer Computerspiele.* E-Lernen: Hybride Lernformen, Online-Communities, Spiele. QEM-Report, 2005(92): p. 241-376.
33. Wiemeyer, J. and S. Hardy, *Serious games and motor learning: concepts, evidence, technology*, in *Serious games and virtual worlds in education, professional development, and healthcare*. 2013, IGI Global. p. 197-220.
34. Bayrakdar, A., Y. Yıldız, and I. Bayraktar, *Do e-athletes move? A study on physical activity level and body composition in elite e-sports.* Physical education of students, 2020. **24**(5): p. 259-264.
35. Kari, T. and V.-M. Karhulahti, *Do E-athletes move?: A study on training and physical exercise in elite E-Sports.* International Journal of Gaming and Computer-Mediated Simulations (IJGCMS), 2016. **8**(4): p. 53-66.
36. Martin-Niedecken, A.L. and A. Schättin, *Let the body'n'brain games begin: Toward innovative training approaches in eSports athletes.* Frontiers in psychology, 2020. **11**.
37. Netz, Y., *Is there a preferred mode of exercise for cognition enhancement in older age?—a narrative review.* Frontiers in medicine, 2019. **6**: p. 57.
38. Ballesteros, S., C. Voelcker-Rehage, and L. Bherer, *Cognitive and brain plasticity induced by physical exercise, cognitive training, video games, and combined interventions.* Frontiers in human neuroscience, 2018. **12**: p. 169.
39. Alesi, M., et al., *Improving children's coordinative skills and executive functions: the effects of a football exercise program.* Perceptual and motor skills, 2016. **122**(1): p. 27-46.
40. Wang, C.-H., et al., *The relationship between aerobic fitness and neural oscillations during visuo-spatial attention in young adults.* Experimental Brain Research, 2015. **233**(4): p. 1069-1078.
41. Iuliano, E., et al., *Effects of different types of physical activity on the cognitive functions and attention in older people: A randomized controlled study.* Experimental gerontology, 2015. **70**: p. 105-110.
42. Greer, T.L., et al., *Dose-dependent changes in cognitive function with exercise augmentation for major depression: results from the TREAD study.* European Neuropsychopharmacology, 2015. **25**(2): p. 248-256.
43. Kamijo, K., et al., *The effects of an afterschool physical activity program on working memory in preadolescent children.* Developmental science, 2011. **14**(5): p. 1046-1058.
44. Yamazaki, Y., et al., *Inter-individual differences in exercise-induced spatial working memory improvement: A near-infrared spectroscopy study,* in *Oxygen Transport to Tissue XXXIX*. 2017, Springer. p. 81-88.

45. Kan, B., C. Speelman, and K. Nosaka, *Cognitive demand of eccentric versus concentric cycling and its effects on post-exercise attention and vigilance.* European journal of applied physiology, 2019. **119**(7): p. 1599-1610.
46. Hotting, K. and B. Roder, *Beneficial effects of physical exercise on neuroplasticity and cognition.* Neurosci Biobehav Rev, 2013. **37**(9 Pt B): p. 2243-57.
47. Legrand, F.D., et al., *Brief aerobic exercise immediately enhances visual attentional control and perceptual speed. Testing the mediating role of feelings of energy.* Acta psychologica, 2018. **191**: p. 25-31.
48. Douris, P.C., et al., *The effects of aerobic exercise and gaming on cognitive performance.* Journal of human kinetics, 2018. **61**(1): p. 73-83.
49. Kramer, A.F., et al., *Exercise, aging and cognition: healthy body, healthy mind.* Human factors interventions for the health care of older adults, 2001: p. 91-120.
50. Altmann, L.J., et al., *Unexpected dual task benefits on cycling in Parkinson disease and healthy adults: A neuro-behavioral model.* PloS one, 2015. **10**(5): p. e0125470.
51. Fernandes M. de Sousa, A., et al., *The influence of exercise and physical fitness status on attention: a systematic review.* International Review of Sport and Exercise Psychology, 2019. **12**(1): p. 202-234.
52. Smith, D.L. and R.P. Claytor, *An acute bout of aerobic exercise reduces movement time in a Fitts' task.* Plos one, 2018. **13**(12): p. e0210195.
53. Dupuy, O., et al., *Higher levels of cardiovascular fitness are associated with better executive function and prefrontal oxygenation in younger and older women.* Frontiers in human neuroscience, 2015. **9**: p. 66.
54. Nagorsky, E. and J. Wiemeyer, *The structure of performance and training in esports.* PloS one, 2020. **15**(8): p. e0237584.
55. Bányai, F., et al., *The psychology of esports: A systematic literature review.* Journal of gambling studies, 2019. **35**(2): p. 351-365.
56. Griffiths, M.D., *The psychosocial impact of professional gambling, professional video gaming & eSports.* Casino & Gaming International, 2017. **28**: p. 59-63.
57. Faust, K., J. Meyer, and M.D. Griffiths, *Competitive and professional gaming: Discussing potential benefits of scientific study.* International Journal of Cyber Behavior, Psychology and Learning (IJCBPL), 2013. **3**(1): p. 67-77.
58. Hamari, J. and M. Sjöblom, *What is eSports and why do people watch it?* Internet research, 2017.
59. DiFrancisco-Donoghue, J., et al., *Managing the health of the eSport athlete: an integrated health management model.* BMJ open sport & exercise medicine, 2019. **5**(1): p. e000467.
60. Lynch, J., *As NFL ratings drop, a new internet study says young men like watching eSports more than traditional sports.* Retrieved October, 2017. **30**: p. 2018.
61. Wingfield, N., *E-Sports at college, with stars and scholarships.* New York Times, 2014.
62. Snider, M., *League of Legends' makes big league moves.* USA Today, 2013.
63. Kane, D. and B.D. Spradley, *Recognizing ESports as a sport.* Sport Journal, 2017. **20**: p. 1-9.
64. Schwartz, N., *More people watch eSports than watch the World Series or NBA Finals.* Obtenido de For The Win from USA Today Sports: http://ftw. usatoday. com, 2014.
65. Funk, D.C., A.D. Pizzo, and B.J. Baker, *eSport management: Embracing eSport education and research opportunities.* Sport Management Review, 2018. **21**(1): p. 7-13.
66. Borowy, M., *Pioneering eSport: the experience economy and the marketing of early 1980s arcade gaming contests.* International Journal of Communication, 2013. **7**: p. 21.
67. Seo, Y., *Electronic sports: A new marketing landscape of the experience economy.* Journal of Marketing Management, 2013. **29**(13-14): p. 1542-1560.
68. Taylor, T.L., *Raising the stakes: E-sports and the professionalization of computer gaming*. 2012: Mit Press.
69. Burroughs, B. and P. Rama, *The eSports Trojan horse: Twitch and streaming futures.* Journal For Virtual Worlds Research, 2015. **8**(2).

70. Holt, J., *Virtual domains for sports and games.* Sport, Ethics and Philosophy, 2016. **10**(1): p. 5-13.
71. Hutchins, B., *Signs of meta-change in second modernity: the growth of e-sport and the World Cyber Games.* New Media & Society, 2008. **10**(6): p. 851-869.
72. Devia-Allen, G.C., *Good game well played: An esports documentary.* 2017.
73. Hamilton, W.A., O. Garretson, and A. Kerne. *Streaming on twitch: fostering participatory communities of play within live mixed media*. in *Proceedings of the SIGCHI conference on human factors in computing systems*. 2014.
74. Cheung, G. and J. Huang. *Starcraft from the stands: understanding the game spectator*. in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2011.
75. Gommesen, N.J., *The Affective Audience in Professional E-sport: An exploration of spectators, and their impact on video game playing.* 2012.
76. Taylor, T. and E. Witkowski. *This is how we play it: what a mega-LAN can teach us about games*. in *Proceedings of the fifth international conference on the foundations of digital games*. 2010.
77. Bryce, J. and J. Rutter. *Killing Like a Girl: Gendered Gaming and Girl Gamers' Visibility*. in *CGDC Conf.* 2002.
78. Taylor, N., *Play to the camera: Video ethnography, spectatorship, and e-sports.* Convergence, 2016. **22**(2): p. 115-130.
79. Witkowski, E., *Eventful masculinities: Negotiations of hegemonic sporting masculinities at LANs*, in *Sports videogames*. 2013, Routledge. p. 225-243.
80. Ruvalcaba, O., et al., *Women's experiences in esports: Gendered differences in peer and spectator feedback during competitive video game play.* Journal of Sport and Social Issues, 2018. **42**(4): p. 295-311.
81. Kim, S.J., *Gender inequality in eSports participation: examining League of Legends*. 2017.
82. Guttmann, A., *From ritual to record: The nature of modern sports*. 2004: Columbia University Press.
83. Hallmann, K. and T. Giel, *eSports–Competitive sports or recreational activity?* Sport management review, 2018. **21**(1): p. 14-20.
84. Hemphill, D., *Cybersport.* Journal of the Philosophy of Sport, 2005. **32**(2): p. 195-207.
85. Jonasson, K. and J. Thiborg, *Electronic sport and its impact on future sport.* Sport in society, 2010. **13**(2): p. 287-299.
86. Suits, B., *The elements of sport.* Ethics in sport, 2007. **2**: p. 9-19.
87. Jenny, S.E., et al., *Virtual (ly) athletes: where eSports fit within the definition of "Sport".* Quest, 2017. **69**(1): p. 1-18.
88. Adamus, T., *Playing computer games as electronic sport: In search of a theoretical framework for a new research field*, in *Computer games and new media cultures*. 2012, Springer. p. 477-490.
89. Lopez-Gonzalez, H. and M.D. Griffiths, *Understanding the convergence of markets in online sports betting.* International Review for the Sociology of Sport, 2018. **53**(7): p. 807-823.
90. Lewis, J., P. Trinh, and D. Kirsh. *A corpus analysis of strategy video game play in starcraft: Brood war*. in *Proceedings of the Annual Meeting of the Cognitive Science Society*. 2011.
91. Drachen, A., M.S. El-Nasr, and A. Canossa, *Game Analytics: Maximizing the Value of Player Data*. 2013: Springer.
92. Nagel, G.L., *Use of eye tracking for esports analytics in a MOBA game*. 2017, The University of Bergen.
93. Kim, J., et al. *The proficiency-congruency dilemma: Virtual team design and performance in multiplayer online games*. in *Proceedings of the 2016 CHI conference on human factors in computing systems*. 2016.
94. Low-Kam, C., et al. *Mining statistically significant sequential patterns*. in *2013 IEEE 13th International Conference on Data Mining*. 2013. IEEE.

95. Pérez, L., et al., *The effects of chronic exercise on attentional networks.* PLoS One, 2014. **9**(7): p. e101478.
96. Ocasio, W., *Attention to attention.* Organization science, 2011. **22**(5): p. 1286-1296.
97. Baddeley, A., *Working memory.* Science, 1992. **255**(5044): p. 556-559.
98. Atkinson, R.C. and R.M. Shiffrin, *The control of short-term memory.* Scientific american, 1971. **225**(2): p. 82-91.
99. Pressley, M., J.G. Borkwski, and W. Schneider, *Good information processing: What it is and how education can promote it.* International Journal of Educational Research, 1989. **13**(8): p. 857-867.
100. Monsell, S., *Task switching.* Trends in cognitive sciences, 2003. **7**(3): p. 134-140.
101. Feng, J., I. Spence, and J. Pratt, *Playing an action video game reduces gender differences in spatial cognition.* Psychological science, 2007. **18**(10): p. 850-855.
102. Green, C.S. and D. Bavelier, *Action video game modifies visual selective attention.* Nature, 2003. **423**(6939): p. 534-537.
103. Li, L., R. Chen, and J. Chen, *Playing action video games improves visuomotor control.* Psychological science, 2016. **27**(8): p. 1092-1108.
104. Schlickum, M.K., et al., *Systematic video game training in surgical novices improves performance in virtual reality endoscopic surgical simulators: a prospective randomized study.* World journal of surgery, 2009. **33**(11): p. 2360-2367.
105. Blacker, K.J., et al., *Effects of action video game training on visual working memory.* Journal of Experimental Psychology: Human Perception and Performance, 2014. **40**(5): p. 1992.
106. Boot, W.R., et al., *The effects of video game playing on attention, memory, and executive control.* Acta psychologica, 2008. **129**(3): p. 387-398.
107. Green, C.S. and D. Bavelier, *Effect of action video games on the spatial distribution of visuospatial attention.* Journal of experimental psychology: Human perception and performance, 2006. **32**(6): p. 1465.
108. Li, R., et al., *Reducing backward masking through action game training.* Journal of vision, 2010. **10**(14): p. 33-33.
109. Green, C.S. and D. Bavelier, *Learning, attentional control, and action video games.* Current biology, 2012. **22**(6): p. R197-R206.
110. Chiappe, D., et al., *Improving multi-tasking ability through action videogames.* Applied ergonomics, 2013. **44**(2): p. 278-284.
111. Strobach, T., P.A. Frensch, and T. Schubert, *Video game practice optimizes executive control skills in dual-task and task switching situations.* Acta psychologica, 2012. **140**(1): p. 13-24.
112. Schubert, T., et al., *Video game experience and its influence on visual attention parameters: an investigation using the framework of the Theory of Visual Attention (TVA).* Acta psychologica, 2015. **157**: p. 200-214.
113. Chisholm, J.D. and A. Kingstone, *Action video game players' visual search advantage extends to biologically relevant stimuli.* Acta psychologica, 2015. **159**: p. 93-99.
114. Chisholm, J.D., et al., *Reduced attentional capture in action video game players.* Attention, Perception, & Psychophysics, 2010. **72**(3): p. 667-671.
115. Chisholm, J.D. and A. Kingstone, *Improved top-down control reduces oculomotor capture: The case of action video game players.* Attention, Perception, & Psychophysics, 2012. **74**(2): p. 257-262.
116. Dye, M.W. and D. Bavelier, *Differential development of visual attention skills in school-age children.* Vision research, 2010. **50**(4): p. 452-459.
117. Dye, M.W., C.S. Green, and D. Bavelier, *The development of attention skills in action video game players.* Neuropsychologia, 2009. **47**(8-9): p. 1780-1789.
118. Gorbet, D.J. and L.E. Sergio, *Move faster, think later: Women who play action video games have quicker visually-guided responses with later onset visuomotor-related brain activity.* PloS one, 2018. **13**(1): p. e0189110.

119. Howard, C.J., R. Wilding, and D. Guest, *Light video game play is associated with enhanced visual processing of rapid serial visual presentation targets.* Perception, 2017. **46**(2): p. 161-177.
120. Hubert-Wallander, B., et al., *Changes in search rate but not in the dynamics of exogenous attention in action videogame players.* Attention, Perception, & Psychophysics, 2011. **73**(8): p. 2399-2412.
121. Krishnan, L., et al., *Neural strategies for selective attention distinguish fast-action video game players.* Brain topography, 2013. **26**(1): p. 83-97.
122. Mack, D.J. and U.J. Ilg, *The effects of video game play on the characteristics of saccadic eye movements.* Vision Research, 2014. **102**: p. 26-32.
123. Morin-Moncet, O., et al., *Action video game playing is reflected in enhanced visuomotor performance and increased corticospinal excitability.* PLoS One, 2016. **11**(12): p. e0169013.
124. Richardson, A.E. and M.L. Collaer, *Virtual navigation performance: the relationship to field of view and prior video gaming experience.* Perceptual and motor skills, 2011. **112**(2): p. 477-498.
125. Sungur, H. and A. Boduroglu, *Action video game players form more detailed representation of objects.* Acta psychologica, 2012. **139**(2): p. 327-334.
126. Appelbaum, L.G., et al., *Action video game playing is associated with improved visual sensitivity, but not alterations in visual sensory memory.* Attention, Perception, & Psychophysics, 2013. **75**(6): p. 1161-1167.
127. Cain, M.S., et al., *Improved control of exogenous attention in action video game players.* Frontiers in psychology, 2014. **5**: p. 69.
128. Clark, K., M.S. Fleck, and S.R. Mitroff, *Enhanced change detection performance reveals improved strategy use in avid action video game players.* Acta psychologica, 2011. **136**(1): p. 67-72.
129. Green, C.S. and D. Bavelier, *Action-video-game experience alters the spatial resolution of vision.* Psychological science, 2007. **18**(1): p. 88-94.
130. Latham, A.J., L.L. Patston, and L.J. Tippett, *The precision of experienced action video-game players: Line bisection reveals reduced leftward response bias.* Attention, Perception, & Psychophysics, 2014. **76**(8): p. 2193-2198.
131. Pavan, A., M. Boyce, and F. Ghin, *Action video games improve direction discrimination of parafoveal translational global motion but not reaction times.* Perception, 2016. **45**(10): p. 1193-1202.
132. Pohl, C., et al., *Gaming to see: action video gaming is associated with enhanced processing of masked stimuli.* Frontiers in psychology, 2014. **5**: p. 70.
133. Colzato, L.S., et al., *Action video gaming and cognitive control: playing first person shooter games is associated with improvement in working memory but not action inhibition.* Psychological research, 2013. **77**(2): p. 234-239.
134. West, G.L., et al., *Visuospatial experience modulates attentional capture: Evidence from action video game players.* Journal of vision, 2008. **8**(16): p. 13-13.
135. Wilms, I.L., A. Petersen, and S. Vangkilde, *Intensive video gaming improves encoding speed to visual short-term memory in young male adults.* Acta psychologica, 2013. **142**(1): p. 108-118.
136. Blacker, K.J. and K.M. Curby, *Enhanced visual short-term memory in action video game players.* Attention, Perception, & Psychophysics, 2013. **75**(6): p. 1128-1136.
137. Cardoso-Leite, P., et al., *Technology consumption and cognitive control: Contrasting action video game experience with media multitasking.* Attention, Perception, & Psychophysics, 2016. **78**(1): p. 218-241.
138. Green, C.S. and D. Bavelier, *Enumeration versus multiple object tracking: The case of action video game players.* Cognition, 2006. **101**(1): p. 217-245.
139. Cain, M.S., A.N. Landau, and A.P. Shimamura, *Action video game experience reduces the cost of switching tasks.* Attention, perception, & psychophysics, 2012. **74**(4): p. 641-647.

140. Donohue, S.E., M.G. Woldorff, and S.R. Mitroff, *Video game players show more precise multisensory temporal processing abilities.* Attention, perception, & psychophysics, 2010. **72**(4): p. 1120-1129.
141. Karle, J.W., S. Watter, and J.M. Shedden, *Task switching in video game players: Benefits of selective attention but not resistance to proactive interference.* Acta psychologica, 2010. **134**(1): p. 70-78.
142. Campbell, M.J., et al., *eSports: A new window on neurocognitive expertise?* Progress in brain research, 2018. **240**: p. 161-174.
143. Segal, K.R. and W.H. Dietz, *Physiologic responses to playing a video game.* American Journal of Diseases of Children, 1991. **145**(9): p. 1034-1036.
144. Wang, X. and A.C. Perry, *Metabolic and physiologic responses to video game play in 7-to 10-year-old boys.* Archives of Pediatrics & adolescent medicine, 2006. **160**(4): p. 411-415.
145. ValladÃo, S.P., J. Middleton, and T.L. Andre, *Esport: Fortnite Acutely Increases Heart Rate of Young Men.* International Journal of Exercise Science, 2020. **13**(6): p. 1217.
146. Gray, P.B., et al., *Testing men's hormone responses to playing League of Legends: No changes in testosterone, cortisol, DHEA or androstenedione but decreases in aldosterone.* Computers in Human Behavior, 2018. **83**: p. 230-234.
147. Sousa, A., et al., *Physiological and cognitive functions following a discrete session of competitive esports gaming.* Frontiers in psychology, 2020. **11**.
148. Siervo, M., et al., *Acute effects of violent video-game playing on blood pressure and appetite perception in normal-weight young men: a randomized controlled trial.* European journal of clinical nutrition, 2013. **67**(12): p. 1322-1324.
149. Fleg, J.L. and E.G. Lakatta, *Role of muscle loss in the age-associated reduction in VO2 max.* Journal of applied physiology, 1988. **65**(3): p. 1147-1151.
150. Iatridis, P.G., *Human circulation: regulation during physical stress.* JAMA, 1987. **258**(22): p. 3316-3316.
151. Lundby, C., D. Montero, and M. Joyner, *Biology of VO2max: looking under the physiology lamp.* Acta Physiologica, 2017. **220**(2): p. 218-228.
152. Fick, A., *Ueber die Messung des Blutquantum in den Herzventrikeln.* Sb Phys Med Ges Worzburg, 1870: p. 16-17.
153. Powers, S.K., E.T. Howley, and J. Quindry, *Exercise physiology: Theory and application to fitness and performance*. 2007: McGraw-Hill New York, NY.
154. Gerstenblith, G., D. Renlund, and E. Lakatta. *Cardiovascular response to exercise in younger and older men*. in *Federation proceedings*. 1987.
155. SALTIN, B., *Physiological effects of physical conditioning.* Med. Sci. Sports, 1969. **1**: p. 50-56.
156. Goodman, J.M., P.P. Liu, and H.J. Green, *Left ventricular adaptations following short-term endurance training.* Journal of applied physiology, 2005. **98**(2): p. 454-460.
157. Åstrand, P.-O., et al., *Textbook of work physiology: physiological bases of exercise*. 2003: Human kinetics.
158. Blomqvist, C.G. and B. Saltin, *Cardiovascular adaptations to physical training.* Annual Review of Physiology, 1983. **45**(1): p. 169-189.
159. Holloszy, J.O. and E.F. Coyle, *Adaptations of skeletal muscle to endurance exercise and their metabolic consequences.* Journal of applied physiology, 1984. **56**(4): p. 831-838.
160. Etnier, J.L., et al., *A meta-regression to examine the relationship between aerobic fitness and cognitive performance.* Brain research reviews, 2006. **52**(1): p. 119-130.
161. Colcombe, S. and A.F. Kramer, *Fitness effects on the cognitive function of older adults: a meta-analytic study.* Psychological science, 2003. **14**(2): p. 125-130.
162. Moreau, D., A.B. Morrison, and A.R. Conway, *An ecological approach to cognitive enhancement: complex motor training.* Acta psychologica, 2015. **157**: p. 44-55.
163. Mohan Chandra, A., et al., *Effect of exercise and heat-load on simple reaction time of university students.* International Journal of Occupational Safety and Ergonomics, 2010. **16**(4): p. 497-505.

164. Audiffren, M., P.D. Tomporowski, and J. Zagrodnik, *Acute aerobic exercise and information processing: energizing motor processes during a choice reaction time task.* Acta Psychologica, 2008. **129**(3): p. 410-419.
165. Chang, Y.-K., et al., *Antecedent acute cycling exercise affects attention control: an ERP study using attention network test.* Frontiers in human neuroscience, 2015. **9**: p. 156.
166. Murray, N.P. and C. Russoniello, *Acute physical activity on cognitive function: a heart rate variability examination.* Applied psychophysiology and biofeedback, 2012. **37**(4): p. 219-227.
167. Nanda, B., J. Balde, and S. Manjunatha, *The acute effects of a single bout of moderate-intensity aerobic exercise on cognitive functions in healthy adult males.* Journal of clinical and diagnostic research: JCDR, 2013. **7**(9): p. 1883.
168. Sato, T., et al., *Brief hourly exercise during night work can help maintain workers' performance.* Industrial health, 2010. **48**(4): p. 470-477.
169. Thomas, R., et al., *Acute exercise and motor memory consolidation: the role of exercise intensity.* PloS one, 2016. **11**(7): p. e0159589.
170. Ashnagar, Z., A. Shadmehr, and S. Jalaei, *The effects of acute bout of cycling on auditory & visual reaction times.* Journal of bodywork and movement therapies, 2015. **19**(2): p. 268-272.
171. Pesce, C., et al., *Acute and chronic exercise effects on attentional control in older road cyclists.* Gerontology, 2011. **57**(2): p. 121-128.
172. Kubesch, S., et al., *Aerobic endurance exercise improves executive functions in depressed patients.* Journal of Clinical Psychiatry, 2003. **64**(9): p. 1005-1012.
173. Chrismas, B.C., et al., *Breaking up prolonged sitting with moderate-intensity walking improves attention and executive function in Qatari females.* PloS one, 2019. **14**(7): p. e0219565.
174. Pontifex, M.B., et al., *Single bouts of exercise selectively sustain attentional processes.* Psychophysiology, 2015. **52**(5): p. 618-625.
175. de Sousa, A.F., et al., *Improvements in attention and cardiac autonomic modulation after a 2-weeks sprint interval training program: a fidelity approach.* Frontiers in physiology, 2018. **9**: p. 241.
176. Sipavičienė, S., et al., *Effect of single physical load of different duration and intensity on cognitive function.* Medicina, 2012. **48**(4): p. 31.
177. Bue-Estes, C.L., et al., *Short-term exercise to exhaustion and its effects on cognitive function in young women.* Perceptual and motor skills, 2008. **107**(3): p. 933-945.
178. Weng, T.B., et al., *Differential effects of acute exercise on distinct aspects of executive function.* Medicine and science in sports and exercise, 2015. **47**(7): p. 1460-1469.
179. Heisz, J.J., et al., *The effects of physical exercise and cognitive training on memory and neurotrophic factors.* Journal of cognitive neuroscience, 2017. **29**(11): p. 1895-1907.
180. Hawley, J.A., et al., *Integrative biology of exercise.* Cell, 2014. **159**(4): p. 738-749.
181. Tsai, C.-L., et al., *The effects of different exercise types on visuospatial attention in the elderly.* Psychology of Sport and Exercise, 2016. **26**: p. 130-138.
182. Vaughan, S., et al., *The effects of multimodal exercise on cognitive and physical functioning and brain-derived neurotrophic factor in older women: a randomised controlled trial.* Age and ageing, 2014. **43**(5): p. 623-629.
183. Barnes, D.E., et al., *A longitudinal study of cardiorespiratory fitness and cognitive function in healthy older adults.* Journal of the American Geriatrics Society, 2003. **51**(4): p. 459-465.
184. Buck, S.M., C.H. Hillman, and D.M. Castelli, *The relation of aerobic fitness to stroop task performance in preadolescent children.* Medicine and science in sports and exercise, 2008. **40**(1): p. 166-172.
185. Luque-Casado, A., et al., *Cognitive performance and heart rate variability: the influence of fitness level.* PloS one, 2013. **8**(2): p. e56935.
186. Netz, Y., et al., *Aerobic fitness and multidomain cognitive function in advanced age.* International Psychogeriatrics, 2011. **23**(1): p. 114.

187. Themanson, J.R., C.H. Hillman, and J.J. Curtin, *Age and physical activity influences on action monitoring during task switching.* Neurobiology of Aging, 2006. **27**(9): p. 1335-1345.
188. Hillman, C.H., et al., *A cross-sectional examination of age and physical activity on performance and event-related brain potentials in a task switching paradigm.* International Journal of Psychophysiology, 2006. **59**(1): p. 30-39.
189. Kamijo, K. and Y. Takeda, *Regular physical activity improves executive function during task switching in young adults.* International Journal of Psychophysiology, 2010. **75**(3): p. 304-311.
190. Voelcker-Rehage, C., B. Godde, and U.M. Staudinger, *Physical and motor fitness are both related to cognition in old age.* European Journal of Neuroscience, 2010. **31**(1): p. 167-176.
191. Weuve, J., et al., *Physical activity, including walking, and cognitive function in older women.* Jama, 2004. **292**(12): p. 1454-1461.
192. Hillman, C.H., et al., *Effects of the FITKids randomized controlled trial on executive control and brain function.* Pediatrics, 2014. **134**(4): p. e1063-e1071.
193. Antunes, H.K.M., et al., *Aerobic physical exercise improved the cognitive function of elderly males but did not modify their blood homocysteine levels.* Dementia and geriatric cognitive disorders extra, 2015. **5**(1): p. 13-24.
194. Gutmann, B., et al., *Effects of physical exercise on individual resting state EEG alpha peak frequency.* Neural plasticity, 2015. **2015**.
195. Hansen, A.L., et al., *Heart rate variability and its relation to prefrontal cognitive function: the effects of training and detraining.* European journal of applied physiology, 2004. **93**(3): p. 263-272.
196. Krogh, J., et al., *II trial. Aerobic exercise versus stretching exercise in patients with major depression—a randomised clinical trial.* PloS one, 2012. **7**(10): p. e48316.
197. Hötting, K., et al., *Differential cognitive effects of cycling versus stretching/coordination training in middle-aged adults.* Health Psychology, 2012. **31**(2): p. 145.
198. Freeborn, T.J., A. Milligan, and M.R. Esco, *Evaluation of ImpediMed SFB7 BIS device for low-impedance measurements.* Measurement, 2018. **129**: p. 20-30.
199. Tombaugh, T.N., *Trail Making Test A and B: normative data stratified by age and education.* Archives of clinical neuropsychology, 2004. **19**(2): p. 203-214.
200. Bruce, R., *Exercise testing of patients with coronary artery disease.* Ann Clin Res, 1971. **3**: p. 323-332.
201. Will, P.M. and J.D. Walter, *Exercise testing: improving performance with a ramped Bruce protocol.* American heart journal, 1999. **138**(6): p. 1033-1037.
202. Reed, J.L. and A.L. Pipe, *The talk test: a useful tool for prescribing and monitoring exercise intensity.* Current opinion in cardiology, 2014. **29**(5): p. 475-480.
203. Schober, P., C. Boer, and L.A. Schwarte, *Correlation coefficients: appropriate use and interpretation.* Anesthesia & Analgesia, 2018. **126**(5): p. 1763-1768.
204. Utter, A.C., et al., *Validation of the Adult OMNI Scale of perceived exertion for walking/running exercise.* Medicine and science in sports and exercise, 2004. **36**(10): p. 1776-1780.
205. Pescatello, L., et al., *ACSM's Guidelines for Testing and Prescription*. 2014, Lippincott Williams and Wikins Baltimore, MD.
206. Page, L. and J. Coates, *Winner and loser effects in human competitions. Evidence from equally matched tennis players.* Evolution and Human Behavior, 2017. **38**(4): p. 530-535.
207. Fuxjager, M.J., et al., *The 'home advantage'is necessary for a full winner effect and changes in post-encounter testosterone.* Hormones and behavior, 2009. **56**(2): p. 214-219.
208. Mujika, I. and S. Padilla, *Cardiorespiratory and metabolic characteristics of detraining in humans.* Medicine and science in sports and exercise, 2001. **33**(3): p. 413-421.
209. Madsen, K., et al., *Effects of detraining on endurance capacity and metabolic changes during prolonged exhaustive exercise.* Journal of applied physiology, 1993. **75**(4): p. 1444-1451.

Appendix A

Additional Data Collection Instruments

Physical Activity Readiness Questionnaire (PAR-Q)

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people, physical activity should not pose any problems or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read the carefully and check YES or NO opposite the question if it applies to you. If yes, please explain.

YES NO

____ ____ 1. Has your doctor ever said you have heart trouble?
Yes, ____

____ ____ 2. Do you frequently have pains in your heart and chest?
Yes, ____

____ ____ 3. Do you often feel pain or have spells of severe dizziness?
Yes, ____

____ ____ 4. Has a doctor ever said your blood pressure was too high?
Yes, ____

____ ____ 5. Has your doctor ever told you that you have a bone or joint problem(s), such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
Yes, ____

____ ____ 6. Is there a good physical reason, not mentioned here, why you should not follow an activity program even if you wanted to?
Yes, ____

____ ____ 7. Are you over age 60 and not accustomed to vigorous exercise?
Yes, ____

____ ____ 8. Do you suffer from any problems of the lower back, i.e., chronic pain, or numbness?
Yes, ____

____ ____ 9. Are you currently taking any medications? If YES, please specify.
Yes, ____

____ ____ 10. Do you currently have a disability or a communicable disease?
Yes, ____

If you answered NO to all questions above, it gives a general indication that you may participate in physical and aerobic fitness activities and/or fitness evaluation testing. The fact that you answered NO to the above questions, is no guarantee that you will have a normal response to exercise. If you answered Yes to any of the above questions, then you may need written permission from a physician before participating in physical and aerobic fitness activities and/or fitness evaluation testing.

______________________ ______________________ ______________________

Print Name Signature Date

Warrior Research Center Health Questionnaire

Name____________________________________ Date__________________ __________

1.Age _______, Birthdate _______Weight (lbs.) _____________ Height_________

2.Do you have Raynaud's Disease? YES
NO

3.Have you had any significant injury within the past 3 months? YES NO

If yes, please explain: ____

4. Are you healthy and have no muscle, nerve, or joint problems that you know of (numbness, tingling, sprains, strains, fractures, joint disease)? YES NO

If yes, please explain: ____

5. Are you currently taking any medications? YES
NO
If yes, please explain: ____

6.Do you currently have a disability or a known disease or health condition (diabetes, heart conditions, ADHD, etc…)? YES NO

If yes, please explain: ____

7.Are you currently taking any supplements other than a multivitamin? YES NO
(Whey protein, creatine, etc...)

If yes, please explain: ____

8.Do you have any other health or fitness related conditions we should know about? YES NO

If yes, please explain: ____

9. Are you allergic or have you ever had any adverse reactions adhesives YES NO

If yes, please explain: ____

10. Have you previously or recently been diagnosed with COVID-19? Date: _____________ YES NO

11. If you answered YES, to question 11; what severity of symptoms did you experience? (Check all that apply)

o Asymptomatic
o Symptomatic – Not-hospitalized
o Hospitalized
o Hospitalized w/ Ventilator Use

12. Have you received your COVID-19 vaccine? Date: ______________ YES
NO

Informed Consent Document

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(NOTE: DO NOT SIGN THIS DOCUMENT UNLESS AN IRB APPROVAL STAMP WITH CURRENT DATES HAS BEEN APPLIES TO THIS DOCUMENT)

INFORMED CONSENT

The Effect of Cardiovascular Exercise on eSport Performance in Smash Ultimate Competitors

You are being asked to take part in a research study. This research study is voluntary, you do not have to participate. The procedures, risk, and benefits are fully described in this consent form. The purpose of this study is to determine if there is an effect of exercise on Smash Ultimate bracket performance. The study is being conducted by Dr. JoEllen Sefton, Professor, Director of the Warrior Research Center and Neuromechanics Research Laboratory in the Auburn University Department of Kinesiology. You were selected as a possible participant because you are a member of the Smash Ultimate Community. You will not be able to participate if you have never competed in an online bracket, or have any injury in the past 3-6 months that would prevent you from participating in cardiovascular exercise. If you are selected for the control group, your total time commitment over the course of 8-10 weeks will be 22.5 hours split between competition in Super Smash Brothers Ultimate Brackets and testing. If you are selected for the exercise group, your total time commitment over the course of 8-10 weeks will be 33 hours split between competition in Super Smash Brothers Ultimate Brackets, testing, and exercise.

Study Summary

You are being asked to take part in a research study. This research study is voluntary, meaning you do not have to take part in it. The procedures, risks, and benefits are fully described further in the consent form. The purpose of the study is to find out if there is an effect of cardiovascular exercise on video game performance. There will be six visits, the first lasting approximately 1 hour, and visits 2-5 lasting approximately 4 hours each. You will be asked to complete baseline testing, which includes body fat measurements, an exercise test, and a brain game. If you are randomly selected for the exercise group, you will be asked to participate in 2 sessions of cardiovascular exercise and an 8 week at home cardiovascular exercise program of our design using the exercise form of your choice (running, bike, elliptical). You will then be asked to compete in 4 structured Super Smash Brother's Ultimate competitions. At the end of the study we will re-do the testing we did to start the study. As with any exercise study, there is risk of discomfort, injury, illness, fall, or death. There is additionally a risk of breach of confidentiality and potential allergic reaction to adhesives. In the exercise group, there are fitness and health benefits of participation in an exercise program. In the control group, there are no foreseeable benefits other than additional exposure to structured competitive bracket play. The alternative to this study is to not participate.

What will be involved if you participate?

1. After you read this informed consent, a member of the research team will be available to answer any questions. If you decide to participate, you will sign the consent form. Choosing to, or not to participate will not affect your relationship with Auburn University, Dr. Sefton, the School of Kinesiology, or the Auburn University Smash Ultimate community.
2. In order to participate you must be a member of the Alabama Smash Ultimate Community with competitive experience in either offline or online brackets recorded through Smash.gg. You must be between ages 16-30 without any disease, illness, or pathology that would preclude full participation in the study or put you at risk of harm. These include: (Please ask if you have questions about any of these conditions):
    a. Acute inflammations and infections
    b. Acute joint disorders/arthroses
    c. Chronic migraine headaches
    d. Cardiovascular diseases, such as heart or vascular issues
    e. Recent joint implants such as foot, knee, and implants
    f. Heart rhythms/valve disorders
    g. Recently placed metal or synthetic implants such as pacemakers
    h. Pregnancy, gallstones, epilepsy
    i. Recent blood clot
    j. Low back complaints such as acute hernia, discopathy, and spondylolysis
    k. Tumors and kidney stones
    l. Have a current concussion
3. You will be given a health questionnaire to complete. We will record your height, weight, sex, and age. You will be assigned a coded participant identification number so we can keep your information private.
4. You will be asked to schedule a time to start the study.
5. Study Timeline:
    a. If you are selected for the exercise group, this study will require 33 hours of your time including the initial meeting, baseline and final data collection, exercise, and Smash Ultimate Brackets. The timeline for the exercise group is listed below. A large portion of your time commitment (16 hours) will be spent competing in Smash

Ultimate Brackets.

eSport Study Timeline	**Exercise Group**
Event	Time (Hours)
Initial Meeting	0.5
Baseline Data Collection	0.75
Competition 1	4
Acute Exercise 1	0.5
Competition 2	4
Week 1 Cardio Program	1.5
Week 2 Cardio Program	1.5
Week 3 Cardio Program	1.66
Week 4 Cardio Program	1.66
Week 5 Cardio Program	1.83
Week 6 Cardio Program	1.83
Week 7 Cardio Program	2
Week 8 Cardio Program	2
Competition 3	0.5
Acute Exercise 2	0.5
Competition 4	4
Post-Testing Data Collection	0.75
Total	33

b. If you are selected for the control group, this study will require 22.3 hours of your time including the initial meeting, baseline and final data collection, and competing in Smash Ultimate brackets. The timeline for the control group is listed below. A majority of your time commitment (16 hours) will be spent competing in Smash Ultimate Brackets.

eSport Study Timeline	Control Group
<u>**Event**</u>	Time (Hours)
Initial Meeting	0.5
Baseline Data Collection	0.75
Competition 1	4
Sedentary Time 1	0.5
Competition 2	4
Competition 3	0.5
Sedentary Time 2	0.5
Competition 4	4
Post-Testing Data Collection	0.75
Total	22.3

<u>**Both Groups**</u>

Initial Meeting [0.5 hours]

1. Meet one or more members of the research team [0.16 hours]
2. Review informed consent to determine if interested in study participation [0.33 hours]

Baseline/Final Data Collection(s) [0.75 hours each]

1. Body Composition [0.16 hours]
2. Trails Task Brain Games (2) [0.16 hours each]
3. Cardiovascular fitness Test [0.25 hours]

Smash Ultimate Semi-Round Robin Bracket [16 hours]

1. Competition 1 [4 hours]
2. Competition 2 [4 hours]
3. Competition 3 [4 hours]
4. Competition 4 [4 hours]

<u>**Exercise group**</u>

Acute Exercise 1 [0.5 hours]

1. Cardiovascular Training [0.5 hours

Acute Exercise 2 [0.5 hours]

1. Cardiovascular Training [0.5 hours]

At Home Exercise [14 hours]

1. Week 1 Cardio [1.5 hours]
2. Week 2 Cardio [1.5 hours]
3. Week 3 Cardio [1.67 hours]
4. Week 4 Cardio [1.67 hours]
5. Week 5 Cardio [1.83 hours]

6. Week 6 Cardio [1.83 hours]
7. Week 7 Cardio [2 hours]
8. Week 8 Cardio [2 hours]

Control Group

Planned Sedentary Time [1 hour]

1. Pre-Competition 2 [0.5 hours]
2. Pre-Competition 4 [0.5 hours]

Testing Procedures

1. Body Composition [10 minutes]

   Body Composition will be obtained through Bioelectric Impedance Analysis

   a. You will be asked to come in to lab hydrated in the morning. You will be asked to refrain from alcohol consumption 12 hours before body composition testing, and refrain from caffeine consumption and exercise 2 hours before body composition testing. To ensure you are hydrated, a member of the research team will ask you to provide a urine sample in a cup, and your urine will be tested for hydration status. If you are not hydrated we will supply you with 16 fluid ounces of water and reassess after 15 minutes. If you are hydrated, we will begin body composition testing.

   b. You will be asked to remove footwear and lay down on your back on one of our massage therapy tables. A member of the research team will clean the top of your foot and the back of your hand with an alcohol swab. Then, they will lightly rub those areas with a gauze pad to remove any dead skin. Afterward, small electrodes will be placed on those areas: 2 on the back of your hand, and two on the top of your foot. A researcher will record your height and weight, and we will record your fat mass, fat free mass, and total body water.

2. Trails Tasks [10 minutes each]

   Trails Tasks are brain games measuring your hand-eye coordination.

   A member of the research team will give you all instructions for the brain games before beginning. You will complete a manual version of the brain game with black pen and paper. You will then complete a digital version of the brain game utilizing your choice of either a Nintendo Switch Pro Controller or a GameCube Controller.

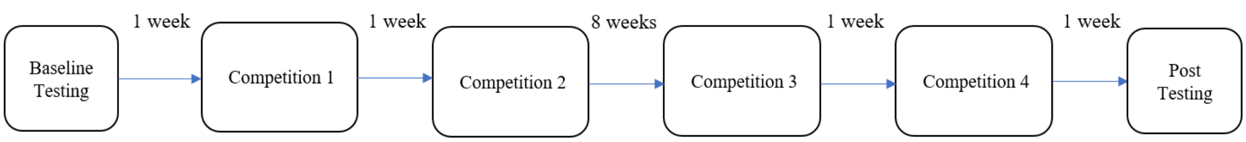
3. VO_2 Max Test [15 minutes]

   VO_2 Max cardiovascular fitness testing is a test that measures your fitness level.

   a. The member of the research team administering the VO_2 Max test will fit you with a 12-lead electrocardiogram Then, you will be fitted with a headgear and mouthpiece through which you will breathe for the entirety of the test. This is an exercise test, so you will be asked to wear athletic attire for the duration of the test.

b. You will be given a 5-minute warm-up at a self-selected pace on the treadmill. When those 5 minutes have elapsed, you will start the test on Stage 1. Stage 1 is a 1.7 mph walk on a 10% grade. Every 3 minutes, the researcher will increase both the speed and the grade of the treadmill. The test will be ended when you are unable to continue at the same pace. You will be asked to give maximal effort through the duration of the VO_2 Max test. Throughout the test the researchers will record measures of heart rate and oxygen consumption, as well your idea of how hard you are working.

4. Competitions [~240 minutes each]
    a. You will be asked to participate in 4 semi-round robin Smash Ultimate competitions. If you are in the exercise group, you will play each member of the control group in a best of 3 and vice versa. These sets will follow the unified Alabama Smash Ultimate Ruleset: (1) 3 stocks, (2) 7-minute timer, and (3) standard stagelist and pick/ban system. At the conclusion of the best of 3 set, game count will be recorded. At the conclusion of each competition, total set count will be recorded. You may play any character at any competition.
    b. The first competition will take place 1 week after baseline testing
    c. The second competition will take place 1 week after competition 1.
    d. The third competition will take place 8 weeks after competition 2.
    e. The fourth competition will take place 1 week after competition 3.
    f. A timeline of the competitions is provided below.



5. Acute Exercise [30 minutes]
    a. If you are in the exercise group, you will be asked to participate in a 30-minutes of cardiovascular exercise before Competitions 2 and 4.
    b. Prior to exercise, you will be assigned a number and fitted with a heart rate monitor to record your exercise intensity while you run . You will not be asked to bring any equipment other than clothing and shoes that you are comfortable running in.
    c. You will line up on the Auburn University Intramural Fields with the rest of the exercise group. When the researcher says "go" you will begin a 5-minute warm-up at a self-selected pace. After warm-up, you will complete the planned running exercise (a combination of running and light jogging) as described by the researcher.
6. At-home Endurance Training [30-40 minutes]
    a. If you are in the exercise group, you will be virtually coached through an at-home cardio program. You will be asked to exercise 3 days per week. You will be allowed to self-select the type of exercise from the following list

   i. Outdoor/Indoor Running
   ii. Outdoor Cycling
   iii. Stationary Bike
   iv. Elliptical
   v. Treadmill Running

b. You will join a Discord video or audio call with a member of the research team who will coach you through the cardiovascular exercise program. On week 1, the cardio program will mimic the exercise you completed on campus. Every session, the intensity will gradually increase. Every week, the total exercise time will gradually increase.

Potential risks and discomforts

1. The risks associated with participating in this study are minimal. You may experience discomfort during exercise. If that is the case, you may stop at any time. Participation in the exercise program is voluntary, and you may stop at any time and discontinue the study. Additionally, you will begin your exercise program at a self-selected pace.
2. As with any exercise program there is a risk of muscle soreness, pain, fall, musculoskeletal injury, or death from participation in either the acute exercise bout or the at-home endurance training program. These are also risks of the exercise testing during the VO2 Max protocol. There is also a risk of heat illness due while running outdoors due to Alabama temperatures. To mitigate discomfort and injury risk, all exercise will be supervised by a member of the research team. Exercise will be completed using a self-selected modality and begins at a self-selected pace. The VO_2 Max testing will be supervised by members of the research team
3. During Bioelectrical Impedance Analysis and VO_2 Max Testing, there is risk of allergic reactions to adhesives. To prevent this risk, we ask that you please provide all adhesive and latex allergies in the Health History Questionnaire. All potential participants who list allergy to adhesives will be excluded from the study.
4. There is a risk of breach of confidentiality. To prevent this all documentation will be locked in filing cabinets in the office of Dr. Sefton. We will only use your participant number on data collection documents so your name cannot be traced to performance outcomes. Performance in the semi-round robin style competitions (Competitions 1- 4) will not be reported to the Auburn Smash Ultimate community or recorded through smash.gg.

COVID 19 Screening and Precautions

The day before any in-person meeting the you will be asked the following questions by either phone or Zoom call.

1. Have you had any of the following symptoms in the past two weeks, even if they were mild?

Fever or chills
Cough
Shortness of breath or difficulty breathing
Fatigue

Muscle or body aches
Headache
New loss of taste or smell
Sore throat
Congestion or runny nose
Nausea or vomiting
Diarrhea

2. In the past three weeks, have you visited another state, country, or facility with sustained (ongoing) occurrence of COVID-19?
3. Have you had close contact with a person that has tested positive for COVID-19 or who is under investigation for possible COVID-19?
4. Is there any additional information you would like to provide related to your possible exposure to COVID-19?

Any YES answer to the listed questions will be considered sufficient enough reason to post-pone in person visits or not enroll you in the study. If you screen positive you will be instructed to contact your primary care provider.

All members of the research team have received both doses of the COVID-19 vaccine. Members of the research team will be wearing N95 masks during all close-contact procedures. You will be required to wear a mask during all in person data collection. During the eSport competitions, all participants will be seated at least six feet apart while competing. To ensure this, each set will be played on a dual monitor setup, with each monitor on separate ends of the table. You will be using your own controller during the eSport competitions. Each seat, table, monitor, and console surrounding area will be sanitized by a member of the research staff between each set. EPA approved disinfectants will be used to sanitize each area by a member of the research staff. Prior to any data collection, you will be asked to sanitize your hands with a solution that is at least 60% alcohol.

What are the possible benefits of participating in this research?

Participants in the control group will receive possible health and fitness benefits of participation in an exercise program. Aside from additional exposure to competitive structured Smash Ultimate brackets, there are no additional benefits for participants in the control group.

Will I have to pay for anything if I take part in this research?

No, there will be no cost to you for your participation. Everything you need will be provided to you by the research team. There are no venue fee or bracket fees associated with any of the Smash Ultimate brackets that will take place during the study. If you own an exercise intensity/heart rate tracker (Smartwatch, Fitbit etc.) you will be asked to wear it during the at-home cardio sessions. If you do not own one, you may choose to purchase one for yourself. If this is not an option, we will be utilizing a validated "talk-test" to determine your exercise intensity. The talk-test does not require any equipment.

Will I be paid for my participation in this research?

You will not be directly paid for your participation in this research. However, participation in this research does qualify you for an 8-week tournament series. Every Friday during the course of the study, Zachary Rightmire will host a Smash Ultimate bracket in the Auburn University Kinesiology building for participant in the research study. These brackets will have no bracket or venue fee. There will be a $150 prize pot and Top 3 Payout (1st $90, 2nd 45, 3rd $15). for each of these brackets. Bracket sets from these tournaments will be recorded and can be sent to you to re-watch and VOD review. The Auburn Smash Ultimate Power Ranking Committee has agreed that placements in these brackets qualify for Auburn Fall 2021 Power Rankings.

How will you protect my privacy and the confidentiality of records about me?

Each person who chooses to participate in this study will be given a participant number maintained on a master sheet. This sheet will be kept locked in Dr. JoEllen Sefton's office in a locked filing drawer. All other data collected will be password locked, saved on an external drive and anonymized. Only the research team will have access to the material.

Forms will be maintained in locked storage. The database will be password protected and accessible only by the project researchers; the database will be on a single computer locked in a personal office that is only accessible to the research investigators. After a period of 3 years, the data will be destroyed.

Authorized representatives of the following groups may need to review your research and/or medical records as part of their responsibilities to protect research participants:

Auburn University Institutional Review Board

What if I decide not to participate in this research?

Your participation in this research is voluntary. You may decline to participate now or stop taking part in this research at any time without any penalty or loss of benefits to which you are entitled. Leaving the study will remove you from further Smash Ultimate brackets that are a part of this study. Deciding not to participate now or withdrawing later does not harm or in any way affect current or future relationships with Auburn University, the School of Kinesiology, or the Auburn Smash Ultimate Community.

If you change your mind about participating, you can withdraw at any time during the study. Your participation is completely voluntary. If you choose to withdraw, your data can be withdrawn if it is identifiable. Your decision about whether to participate or to stop participating will not jeopardize your future relations with Auburn University, School of Kinesiology, or the Auburn Smash Ultimate Community.

Your privacy will be protected. Any information obtained in connection with this study will remain confidential. Participant information, if published, will be submitted anonymously.

WHO SHOULD I CALL IF I HAVE QUESTIONS OR CONCERNS ABOUT THIS RESEARCH?

If you have questions about the research at any time, you should contact Dr. Sefton at (334) 844-1694 or jmsefton@auburn.edu or Zachary Rightmire at (859) 835-5112 or zbr0001@auburn.edu

If you have any questions about your rights as a research participant, you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board by phone (334) 844-5966 or email at hsubject@auburn.edu or IRBchair@auburn.edu.

SIGNATURE OF RESEARCH PARTICIPANT

I have read the information provided above. I have been given an opportunity to ask questions, and they have all been answered to my satisfaction. Having read the information provided, you must decide whether or not you wish to participate in this research study.

Your signature indicates your willingness to participate.

____
Printed Name of Participant

______________________________ ______________________
Signature of Participant Date

<u>SIGNATURE OF PERSON OBTAINING CONSENT</u>

My signature certifies that the participant signed this consent form in my presence as his/her voluntary act and deed.

____
Printed Name of Person Obtaining Consent

______________________________ ______________________
Signature of Person Obtaining Consent Date